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DAYLIGHT.*

BY

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LADIES AND GENTLEMEN: Shortly after I sent in my subject to Dr. Owens, in response to his kind invitation to me to speak here this evening, I chanced to discover that a lecture on an almost identical topic had been given before the Franklin Institute by the late Henry Morton. His theme was "Sunlight and Moonlight." This, however, was some forty years ago, and most of what I shall have to say to-night is based on newer work, and will not greatly infringe on this earlier paper.

Daylight is simply the light of the sun, modified by its passage through our atmosphere, and further modified by the addition of light, which, having reached the atmosphere, is reflected back and forth and reaches us in the form of skylight. The light from the sky differs from direct sunlight because of the selective reflection to which it has been subjected at the surface of cloud masses and of the earth itself and from particles of dust and moisture in the air.

The effect of the selective absorption of the atmosphere is very marked, as may be seen from the curve in Fig. 1, which is plotted from data given by Dr. Abbot, of the Astrophysical Observatory of the Smithsonian Institution. The values were obtained by making use of numerous sets of observations of the sun's spectrum taken at various localities.

At .8μ, or just beyond the red end of the visible spectrum, about eight per cent. of the sun's rays are cut off by the atmos-

* Presented at the stated meeting held December 20, 1911.

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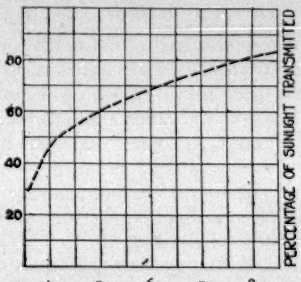
phere, whereas in the violet at least half the light is absorbed, and the sharp downward trend of the curve would seem to indicate complete opacity of the air for a greater portion of the ultra-violet rays. It is on this account that the spectrum of sunlight ends so soon after the boundary of the visible spectrum is passed, and that many rays which appear in the spectra of artificial sources of light near at hand are absent from the spectrum of the sun.

In clear weather, daylight is nearly all direct sunlight. A white surface exposed to the sun and to the whole sky receives about eighty-five per cent. of the light which illuminates it directly from the sun, and only about fifteen per cent. from the other portions of the dome of the sky. In cloudless weather, therefore,

FIG. 1.



Selective absorption of light by the atmosphere.

daylight differs but little from sunlight, for even marked changes in the reflected light from the sky would produce but little effect upon the blended illumination from sun and sky.

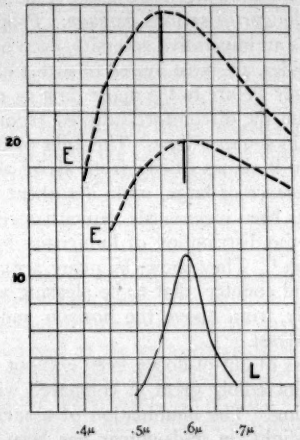
To tell what sunlight is like, outside of our atmosphere, is not a very simple matter, but by going to greater and greater heights above the sea, and making observations upon its constitution, we can estimate its original character as it reaches the upper limits of the earth's atmosphere. By such methods we can indeed form a very good idea of what sunlight would be like if we could entirely remove this blanket or sea of vapor at the bottom of which we live, and could see the sun as it really is.

Daylight, as we get it after its passage through this great atmospheric filter, is of very great importance and interest to us,

because mankind has been brought up in it and, by long exposure to this particular form of illumination, has become thoroughly adapted to it. Daylight, in spite of the increasing use of artificial illumination, is still the normal stimulus of the human eye. The eye is most sensitive to those rays which in the spectrum of sunlight are of maximum energy.

How exact the coincidence is may be seen from Fig. 2, in which L is the ordinary luminosity curve of the eye and E is a portion of the curve giving the distribution of energy in sunlight.

FIG. 2.



Coincidence of maximum of the sensitiveness of the eye and of the sun's energy.

Doubtless this is not a mere coincidence, but the result of gradual adaptation of the race to the particular stimulus to which the human eye has so long been subjected.

On the surface of a planet with an atmosphere as transparent to the violet and ultra-violet as to the longer wave-lengths of the visible spectrum we should expect to find beings the maximum sensitiveness of whose eyes would be considerably displaced towards the violet, so as to correspond to the crest of the curve E^1 in Fig. 2, which is the energy curve of sunlight before its passage through the earth's atmosphere.

The eye, in order to meet all the demands upon it, must of necessity have an extremely wide working range. It has to serve not only at noonday, but also at morning and at evening, and within doors and at night. It is never normally exposed to anything of greater intensity than full daylight, and we find, accordingly, that its range of sensitiveness is such that broad daylight represents the upper limit of what we can endure without danger. We feel no discomfort out of doors when the sun is at its highest, but, under a very slight further increase of intensity, the eye does begin to suffer. Upon a snow field in the summer time, for example, in mountain climbing, the eye is overpowered, and, unless protected, is in danger of serious damage. Proper snow-goggles are recognized as an imperative necessity, even by those who, like the mountain guides, are most inured to such exposure.

How very near we are to the upper limit of endurable brightness appears from the discomfort suffered from the glare of an unshaded street in summer time. The light of the open is pleasurable only when it comes chiefly from above and the eye is relieved by the presence of large, dark, absorbent areas in the line of sight. This has been ingeniously demonstrated in a recent and skilful study of the distribution of luminosity in nature by Drs. Ives and Luckiesh.[1] They show, by many actual measurements made in town and country, that to be pleasing a landscape must be lighted mostly from above the horizon and have a certain abundance of contrast.

The brightness of out-of-doors, even without snow underfoot, is really almost incredibly great as compared with what we use in artificial lighting. The illumination of a surface, exposed to sunlight and skylight, in midsummer has been found to reach 100,000 hefner-meters or 90,000 candle-meters in midsummer.[2] In the suburbs of Berlin, another estimate, by Vogel, was 78,000 hefner-meters, and even in the smoky city of Chicago, in the month of June, Dr. Basquin found 33,000 hefner-meters. When we consider that about 12 hefner-meters, or a candle-foot, is sufficient illumination for easy reading of ordinary print, we realize

[1] Ives and Luckiesh: *Transactions of the Illuminating Engineering Society*, p. 687 (1914).

[2] Occasional isolated values run even higher, and Weber, the inventor of the Weber photometer, gives as the highest record 154,300 hefner-meters. (See Pernter and Exner, "Meteorologische Physik," p. 712.)

what an enormous step down it is from the maximum of full daylight to the minimum which we find necessary for our uses. The sensitiveness of the eye, however, has by no means reached its lowest limit here. All sense of light is not lost until we have descended to an illumination of about 1/1,000,000 of a hefner-meter. From broad daylight, which represents the upper limit, to the almost utter darkness in which we can still see our way about we have a range of usefulness in the human eye for which it is hard to find a parallel.

It is not in the matter of intensity only that the eye exposed to ordinary daylight is near the danger line. Such light contains very nearly the maximum amount of ultra-violet rays that can be borne with impunity.

Sunlight of the sort which exists above the earth's atmosphere, even if the total energy of radiation were not increased, would probably soon destroy the eyesight of an inhabitant of the earth's surface. Even in climbing the higher snow mountains (4,500 to 5,500 meters) where the barometric pressure falls to about half an atmosphere it is necessary to protect the eyes, by means of colored spectacles, quite as much against the excessive amount of ultra-violet radiation as on account of the glare. The extraordinary blue-violet sky at such altitudes, described by Tyndall and other observant mountaineers, and familiar to all climbers, is indicative of the change in composition of daylight due to the greatly reduced thickness of the atmospheric light filter.

The other end of spectrum, where the energy is thousands of times as great as in the ultra-violet, has no such effect. One may sit by the firelight until he burns the skin without hurting his eyes, but a mere glance at the mercury arc in a quartz tube or at certain flaming arcs without the protection of an intervening screen of glass may endanger the eyesight.

Daylight, of course, varies in brightness with the height of the sun above the horizon, and, in the temperate zones, the annual range is much greater than most people, excepting, perhaps, the photographers, are apt to suppose. Fig. 3 contains a curve from observations taken in Germany[3] by L. Weber.

The curve is irregular on account of the occurrence of a long period of dark weather in June. If measurements were made in

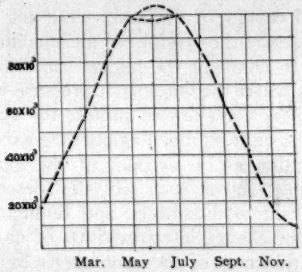
[3] For these and further European data see Pernter and Exner: *l. c.*

some cloudless region, such as Arizona or the Desert of Sahara, the curve would probably be quite symmetrical with the maximum at midsummer.

Observations made by Basquin [4] in Chicago entirely confirm Weber's values, and he also finds that the average brightness of daylight in midwinter is only one-tenth [5] of that in June, and that the ratio between winter and summer in this respect is nearly the same in the United States as in Europe.

One might naturally expect that the daily range of the intensity of daylight would be expressed by a somewhat similar curve having a maximum precisely at noon, but this is not strictly the case, as will be seen from Fig. 4, which contains a set of curves

FIG. 3.



Annual range in the brightness of daylight (measured at Kiel, Germany, by L. Weber).

taken by the author on a cloudless day in Switzerland. In all of these curves, which show the variation in the brightness of four regions of the spectrum from dawn until dusk, there is pronounced dissymmetry; the light in the afternoon being brighter than that at the corresponding time before noon. The ordinate for 4 P.M. of the curve marked "Green .530μ" corresponds, for example, to that for 9.30 A.M.; that is to say, four hours after the sun had passed the meridian the amount of daylight was as great as at two and a half hours before noon. Similarly, the

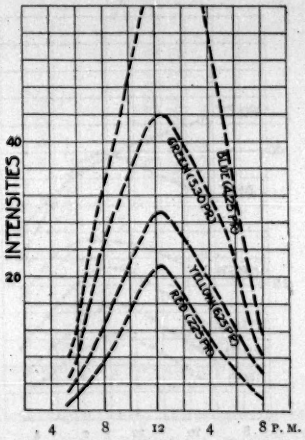
[4] Basquin: *l. c.*

[5] The range between the very brightest day in summer and the darkest in December is vastly greater; the ratio, according to Weber, being nearly 300: 1.

brightness for 6 P.M. was equal to that at 7 A.M. This excess of brightness in the later portions of the day is common to all portions of the spectrum. Observations by Basquin, in which the light was measured without dispersion, exhibit the same characteristics.

In unsettled weather the changes in the course of a day may naturally be much more erratic. Even when there is no very obvious variation in the appearance of the sky, the various portions of the visible spectrum may undergo very different sorts of

FIG. 4.



Daily range in the brightness of daylight.

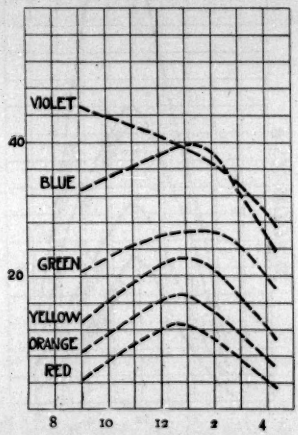
variation, as may be seen from the curves in Fig. 5, which are from observation made during an April day at Palermo, Italy.

In this case the range was nearly normal for the red; but the preponderance of green and blue in the early afternoon was very marked, and the maximum was not reached until about 2 P.M. The violet decreased steadily in amount throughout the day. To what this lack of symmetry in the curves for the daily range in daylight is due will be considered in a later paragraph of this paper.

A point about which there is apt to be misconception on the

part of those who have not paid particular attention to the subject concerns the relative brightness of clouded and unclouded skies. We think of the unclouded sky as bright, but, in point of fact, it is just about as bright as a densely clouded sky, and all the intervening stages of cloudiness are brighter than either. I had an opportunity, a few years ago, of measuring the brightness of the sky in the zenith on an afternoon during which, in the course of a few minutes, as sometimes happens in mountainous regions, the sky passed from an unclouded condition to that of being densely

FIG. 5.



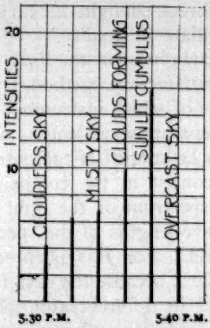
Variations in brightness during April day in Palermo, Italy.

overcast. The observations were made in a high valley in the Tyrol, where, as frequently happens in summer, showers come up with great suddenness. The results of my measurements, which are given in Fig. 6, cover a time interval of only ten minutes, from 5.30 to 5.40 P.M. The sky at 5.30 was cloudless, but it began very rapidly to thicken up with mist. Two minutes later the brightness had materially increased, as shown in the curve. It then remained almost stationary for two minutes, after which it became rapidly brighter and brighter as shreds of sunlit clouds appeared and gathered into shining masses of cumulus.

Then quite suddenly after eight minutes of observations the clouds closed in, the sun disappeared, and it began to rain. Just before I was driven from my post by the downpour, namely, at 5.40, the brightness of the sky in the zenith was almost exactly what it had been ten minutes before, when no cloud in that portion of the sky was visible.

Daylight under the conditions of overcast sky consists of all skylight and no direct sunlight, whereas with unclouded sky, as has already been pointed out, 85 per cent. comes directly from the sun and only 15 per cent. from the sky. The intensity of

FIG. 6.



Variations of brightness with state of sky.

daylight under these conditions, although the sky in the two cases is equally bright, would obviously be quite different.

Of the various theories concerning what we call the color of the sky, an interesting one is that of Spring,[6] the Belgian physicist, who pointed out that both oxygen and ozone in the liquid form are blue when viewed by transmitted light; also, that water when pure is blue, although not to the same extent. He regarded the blue color of these components of the atmosphere as the main cause of the color of the sky, since those rays which reach the eye after reflection, and perhaps after multiple reflections within the atmosphere, will have passed over a longer path in this absorb-

[6] Spring: Bulletin de l'Academie de Bruxelles, 1898, p. 504.

ing medium than the direct rays from the sun. Whatever effect this color of the atmosphere itself may have, it is certain that the sky would have a blue color aside from any effect of selective absorption in passing through it.[7] The atmosphere is a turbid medium, and selective reflection from minute particles suspended in it, in accordance with Rayleigh's formula, would produce what may be called the ideal sky. These actual skies sometimes approach, but they never quite correspond to, it. In general we may say that the effect of reflection by the particles of the atmosphere is to give us light, which is distinctly bluer than that transmitted directly from the sun, but which is rarely or ever as blue as the ideal sky. Daylight, being a mixture of this bluer light from the sky with direct sunlight in varying proportions, will therefore be intermediate in quality.

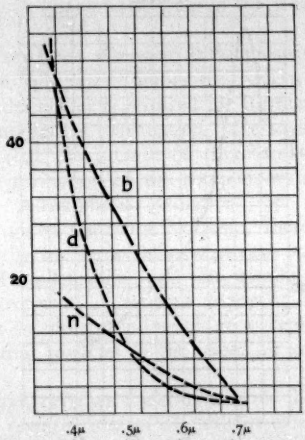
In the study of daylight or of the light from the sky the only really definite and satisfactory method is that of the spectrophotometer, by means of which instrument it is possible to measure as many of the separate wave-lengths of the visible spectrum of which the light to be studied is composed as one may desire. The measurements consist in the comparison, wave-length by wave-length, of the spectrum of the light to be described with the corresponding wave-lengths of the spectrum of some source of known composition. For this purpose sunlight itself will hardly do for a standard, because the rays from the sun at different times of day and in different atmospheric conditions vary very greatly both in intensity and in composition. It is better, therefore, to make comparisons with some standard source of artificial light, and the best available source is the acetylene flame, the composition of which is very nearly uniform, while it possesses the valuable property of relatively great strength in the blue and violet as compared with incandescent lamps or with the flames of ordinary illuminating gas or petroleum.

With a special form of spectrophotometer, one collimator of which points toward the zenith or towards some other selected region of the sky, while the other collimator is illuminated by means of an acetylene lamp properly regulated and adjusted, it is possible to study the composition of the light from the sky very

[7] For an excellent and judicious discussion of the various theories of the color of the sky see Chr. Jensen, "Das Weltall," p. 37, 1904–1905.

conveniently and rapidly. If with such an instrument we begin at dawn and work at intervals through the day, we find certain progressive changes occurring in addition to the increase and decrease in total brightness. These changes, which depend upon the weather, are not the same every day, but on bright mornings, before sunrise, the type of curve which one gets, and which I have called the typical dawn curve, is almost always the same, and this curve comes closer to that which would be obtained from observations of the ideal sky of Rayleigh than anything which

FIG. 7.



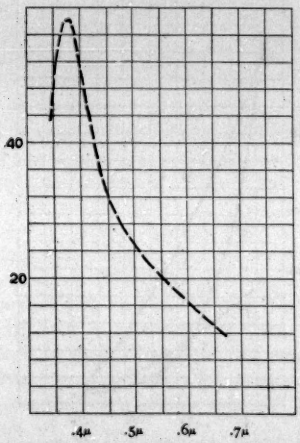
Relative qualities of daylight at dawn and after sunrise.

one gets later in the day. The form of these typical dawn curves and of the corresponding curve after sunset may be seen in Fig. 7 (curve *d*), in which ordinates are the ratio of the brightness of the spectrum of the sky to that of the acetylene flame used for comparison, and abscissæ are wave-lengths. Curves taken on any clear morning or evening when the sun is below the horizon will be found to approximate very closely to this example.

After sunrise there is a rapid increase in the brightness of all portions of the spectrum of skylight, but the brightness of different wave-lengths does not increase at the same rate. In other

words, it is not a mere brightening of the sky we observe, but a change in its color as the day progresses. How great this change is can be seen from curve *n* as compared with the typical dawn curve *d*. Curve *n* was taken in the middle of the morning of the same day. The scales chosen are such as to make the two curves cross each other in the red. It will be seen, however, that this equality does not persist throughout the spectrum, but that the relative brightness in the yellow and green is greater and in the blue and violet less than before sunrise. On exceptional days the red and

FIG. 8.



blue may remain of the same relative brightness, as shown in curve *b*, the middle of the spectrum showing greater increase; but in general, when the sun is well above the horizon, the sky is less blue than in the morning, and its light approaches more closely to that of direct sunlight.

This modification in the light of the sky is probably due in great part to a gradual gathering of particles of moisture, and the changes in the curves as the day progresses will often enable one to predict what kind of an afternoon is to be expected, especially whether there will be a gathering of cumulus and perhaps

showers in the afternoon. I found in the mountain valleys of Switzerland, where many measurements were made, a very peculiar development in the violet of the spectrum of the sky occurring gradually during the later morning and lasting late into afternoon which seemed to be an almost certain forerunner of the gathering of cumulus clouds. On such occasions, beginning about 9 o'clock in the morning, an emission band appears with its maximum in the blue, which increases steadily in intensity until after mid-day and then gradually disappears as evening approaches. Unless the sky becomes overcast it is possible to follow the accession and diminution of this phenomenon and its final disappearance at sunset. A characteristic curve for this type of sky is given in Fig. 8.

Professor Very [8] has discussed these measurements which I first described in two papers before the American Physical Society,[9] to which the reader is referred for further details, and has offered a very suggestive explanation. He says:

"I suggest that the growth of this band is possibly connected with the formation of the complex water molecules described in my 'Atmospheric Radiation' (p. 100), to which Sutherland has given the name hydrols. Increasing ionization of the upper air by the sun's ultra-violet rays lead to the formation of nuclei of condensation, and this, combined with the mid-day upward movement of aqueous vapor at considerable altitudes, conduces to the formation of an exceptional amount of peculiar diffracting particles in the upper air during the middle of the day."

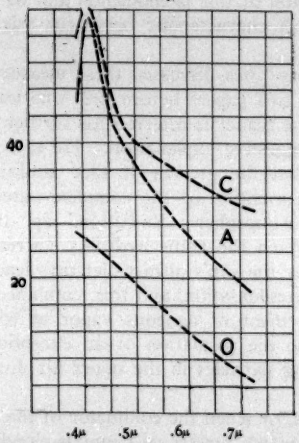
On misty days, or when the collimator of the spectrophotometer is directed towards masses of cumulus cloud illuminated by the sun, the intensity of the green, yellow, and red rays of the spectrum is further greatly increased. As may be seen in Fig. 9, which contains a group of curves showing the character of the light of the sky during a time of light mist or fog (curve *A*), the light from cumulus clouds (curve *C*), and, for purposes of comparison, the light of an overcast sky (curve *O*), it will be seen that these three curves differ chiefly in that the two first, *A* and *C*, show the maximum in the blue already described, whereas the same is nearly or quite absent in curve *C*. Curve *C*

[8] F. W. Very: *Astrophysical Journal*, xxxiv, p. 372, 1911.
[9] Nichols: *Physical Review*, xxvi, p. 498, and xxviii, p. 123.

rises to higher ordinates towards the red end of the spectrum, indicating that sunlit cumulus is less blue than fog or overcast sky.

A comparison of curves made during the day, when the sun shines on the surface of the earth and is reflected back, shows that the earth has also had a modifying influence. Measurements taken at sea are entirely different from those made on shore, especially in the summer time, when the surrounding country is clothed with green foliage. In the latter case we have actually reflected back from the green leaves a weak but unmistakable

FIG. 9.

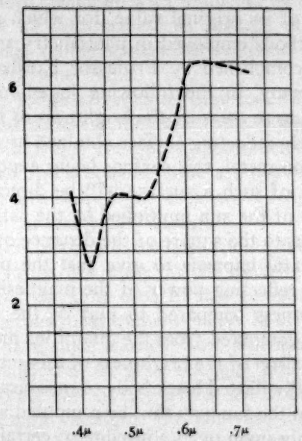


Characteristic curves for Mist (*A*), Cumulus (*C*), and Overcast Sky (*O*).

absorption spectrum containing the bands of chlorophyl. In Fig. 10 a curve is presented which may suffice to illustrate this effect. In it the ratio between the intensities of a daylight spectrum at 8.25 A.M. to that of the corresponding wave-lengths in the typical dawn curve is plotted. The positions of the maximum and the minimum intensities are such as to indicate that the selectivity is partly due, as has already been hinted, to the absorption of light by green leaves. Measurements made at sea or over a sufficiently large snow field in winter do not show these peculiarities.

A sufficient number of examples of the spectrum of daylight under various conditions has been given to indicate the very considerable range of brightness and composition according to the locality, the time of year, the time of day, and the condition of the sky which one meets with in the study of this subject. These fluctuations are much greater than the fluctuations of any given type of artificial light. Our sources of artificial illumination, from the candle to the tungsten lamp, represent a comparatively small range of temperature, and these temperatures are

FIG. 10.



Ratios of daylight to dawn, curves showing selective reflection by the surface of the earth.

so much lower than that of the sun that the distribution of intensities in all such sources is necessarily of an entirely different character from that of the spectrum of daylight. In the former case we have to do with continuous spectra emanating from glowing carbon or from incandescent metals, such as tantalum or tungsten heated to temperatures lying, approximately, between 1500° C. and 2200° C. Even the carbon arc-light, in spite of the high temperature of the crater (3600° C.), can hardly be assigned a temperature above 2500° for the aver-

age of its radiation. As to the sun, whose temperature was in earlier days variously estimated by indirect and inadequate methods as between 5000° and 100,000°, the development of our knowledge of the laws of radiation and the perfecting of the art of optical pyrometry afford the means of making fairly accurate determinations.

The problem, stated in its simplest terms, consists in reducing the visible radiation from the sun, which is enormous when compared with that of a black body of measurable temperature with which it must be compared, to something like the same brightness. For this purpose the sun's light must be diminished to about .00002 of its original value, for which purpose none of the ordinary methods employed in photometry suffice. This has recently been accomplished by Professor Kurlbaum,[10] of Charlottenburg, Germany, in the following ingenious manner. Instead of attempting to measure the brightness of the sun itself, he observes a diffusely reflecting surface obtained by depositing magnesium oxide upon metal, this surface being exposed to sunlight. The illumination of such a surface will be directly proportional to the brightness of the sun multiplied by the ratio of the square of the sun's radius to the square of the distance of the earth from the sun. This ratio happens to give just the proper reduction demanded. The reflecting power of the magnesium oxide being known, its brightness compared to that of the sun which illuminates it can be computed from the quantities mentioned above; and by the comparison of the brightness of this sunlit surface with that of an artificially-heated black body of measurable temperature the temperature of the sun may thus be computed with an accuracy which depends only upon our knowledge of certain distances and constants and of the laws of radiation. Kurlbaum estimates by this method that the temperature of the sun lies between 6002° and 6023°, an uncertainty which arises chiefly from the inaccuracy of our scales of measuring temperature. Now, between 2000° and 6000° radiation differs so greatly, both in intrinsic brightness and in composition, that sunlight or daylight is in an entirely different class from ordinary artificial illuminants; and, since we cannot, at present, produce incandescence approaching that at 6000°, we are unable to imitate sunlight, except in two

[10] Kurlbaum: *Berichte der Preussischen Akademie der Wissenschaften*, p. 541 (1911).

ways. Certain bright line spectra of glowing vapors, the composition of whose light is really altogether different from the continuous spectrum of the sun, may have the power of stimulating the three primary sensations of red, green, and violet in nearly the same proportions; and thus, as in the case of CO_2 in vacuum tubes under certain conditions, may be made to simulate sunlight in some respects. All known solids, at temperatures of incandescence attainable in practice, are, however, relatively much stronger in red and weaker in the violet than daylight.

Candles, oil and gas flames; the Nernst filament and mantle burner; glow-lamps, whether with filaments of carbon, tantalum or tungsten, are all intermediate as regards the distribution of intensities in their visible spectra between the Hefner standard lamp and the acetylene flame.

How small a range of variation they cover as regards quality of light, and how different they are from daylight, may be seen from Fig. 11, in which the spectrophotometric curves for the Hefner lamp and the acetylene flame are drawn.[11] In this diagram, ordinates are values for each wave-length of the ratios Hefner/daylight or acetylene/daylight.

The brightness of the spectra is so chosen for ease of comparison that these ratios are unity in the yellow region (0.590μ). The standard for daylight used in this comparison is from the average of numerous measurements taken in all sorts of weather, during what I have since learned from European meteorologists was an abnormally dull or gray season. Had the observations been confined to the sort of day which one would naturally select on which to sample daylight, the contrast with these artificial sources would have been much more striking.

Now, while we cannot increase the degree of incandescence of these sources of low temperature so as to make them approach appreciably nearer to sunlight, it is possible to change the quality of their light by the use of properly selected color screens, and this is the second of the two possible methods to which reference is made above.

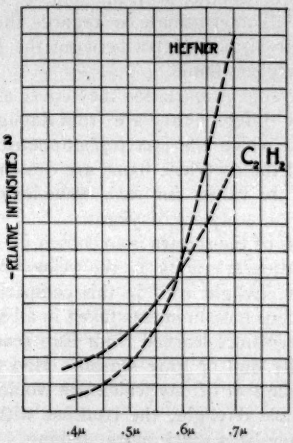
When we try the experiment by placing over half of the field of the lantern a blue screen which gives a fair match as

[11] Nichols: "Daylight and Artificial Light," *Transactions of the Illuminating Engineering Society*, 1908 (May).

to color with daylight, and, by means of a carefully-chosen amber screen, reduce the other half to the color of candle-light, we get, as you see, by direct appeal to the senses, a telling realization of the significance of these curves in Fig. 11, and we have brought home to us the very great difference between the light of the heavens and that by which the greater part of our indoor work is done.

Fortunately the preponderance of the longer wave-lengths in artificial light is one which is restful rather than harmful

FIG. 11.



The distribution of intensities in the spectra of the Hefner lamp and the acetylene flame compared with daylight.

to the eye (which bears excess of violet and ultra-violet so ill), and it is doubtless more healthful to work under a ruddy illumination of fifty candle-meters than to strain the eyes with the two or three candle-meters of cold daylight, which, according to recent measurements,[12] is all that reach the pages of readers in the rooms of many public libraries.

[12] "Nature," 88, p. 600, an abstract of L. Weber's recent Study of Daylight in *Schriften des Naturwissenschaftlichen Vereins für Schleswig-Holstein*, XV, i.

SOME EXPERIMENTS IN "WIRED-WIRELESS" TELEGRAPHY FOR FIELD LINES OF INFORMATION FOR MILITARY PURPOSES.*

BY

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THE Signal Corps of the army at present uses for the service of the mobile forces radio-communication for cavalry operations, and insulated field wire laid on the ground and operated by "buzzers" for infantry and mixed commands. Pure radio-communication is ideal for rapidly moving troops, but has the inherent defect that interference is always possible, and that information may under certain conditions be received by the enemy. Radio methods and field wire methods have, however, taken their places as permanent means of electrical intercommunication in war. At present, the apparatus and the operation of these two methods are distinct and separate. The subject of this paper pertains to some preliminary experiments involving a useful combination of these two methods for field service.

It should be distinctly understood that it is not proposed to do away with either pure radio-communication for field service, or the ordinary "buzzer" operation of wires, which latter has for so many years shown its great reliability in the field. It is rather proposed to supplement these methods by a combination of the two, which, under certain conditions of field service, it is believed will offer cardinal advantages.

At the headquarters of a division or field army there will always be under the Chief Signal Officer a wireless equipment and also several wire lines radiating out from headquarters to the units of the command. So far as these headquarters are concerned, therefore, we have at present the full equipment required for operating "wired-wireless" telegraphy for military purposes.

APPLICATION OF PORTABLE QUENCHED SPARK SET TO STANDARD SIGNAL CORPS FIELD WIRE.

The standard Signal Corps field wire at present furnished consists of 11 strands of steel and one strand of copper, with

* See "Electrical Methods of Intercommunication for Military Purposes," by George O. Squier, Ph.D., JOURNAL FRANKLIN INSTITUTE, 172, 545.

a weight of about 70 pounds per mile and a resistance of about 11 ohms per mile. It is well known that electric waves are not transmitted as efficiently over iron wires as they are over copper wires. The greater the conductivity of the wire conductor, the less the line losses and hence the less the attenuation of the electric waves guided thereby. In addition, it is well known that in all experiments with high-frequency electric waves, where tuning to resonance is used, it is desirable that no iron should be employed. The results given below for field wire are, therefore, inferior to what would be obtained with copper conductors.

The latest apparatus of the Signal Corps for wireless sets employs a 500-cycle generator developed for use on aëroplanes and "pack" sets, with a specially designed transformer and a quenched spark gap as distinguishing features. In the first experiments, the 500-cycle generator was driven by a direct-connected motor which was operated from power taken from a socket connection to a 110-volt electric lighting circuit. The generator delivers power at 110 volts with an output of about 125 watts. The spark gap was of the regular Signal Corps type, consisting of built-up discs of copper, separated by layers of mica ring insulation, and was practically noiseless in operation.

The coupling employed was inductive in type and variable within wide limits, permitting the voltage and the current impressed upon the line to be controlled at will. Convenient tuning elements were available for insertion in the line at the transmitting end. With this arrangement the general efficiency of transmission of electric waves along the ordinary type of field wire described above was observed, the actual wave-length being about 400 meters as measured by a wave meter. The line wire was laid out in the ordinary manner upon the ground, and extended from the Signal Corps laboratory at the Bureau of Standards to improvised stations in the field at the end thereof. At the receiving end the regular wireless detector and high-resistance head-telephones were used.

ELECTRIC WAVE TRANSMISSION OVER OPEN CIRCUIT LINE.

Simple experiments showed that with a transmitting current of a few milliamperes loud signals were easily heard at the receiving end, using the "perikon" detector supplied in the field pack sets, without the necessity of any tuning either at the trans-

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mitting or receiving end. When, however, an "audion" detector was substituted for a perikon it was noted that signals were heard when the receiving end of the wire was connected to one of the terminals of the audion, the other being entirely free, whereas, if the terminals were reversed, nothing was heard. The audion is a detector of the vacuum type in which an ionized path is provided between two insulated terminals inside the vacuum tube. Such a path is known to possess strong unilateral conduction for electric waves, and it was observed that when the free end of the wire was connected to the so-called "grid" terminal signals were heard, whereas they were entirely suppressed when the other terminal was used. This phenomenon had been previously noted in the Signal Corps laboratory in 1910, in connection with experiments on multiplex telephony and telegraphy by means of electric waves guided by wires. The reason for this seems to be that when electric waves are guided along a wire to its free end, they are there reflected, the end of the wire becoming a node of current and loop of potential. In the theoretical case, when an electro-magnetic wave is reflected at the open end of a wire, the magnetic component is suppressed at the moment of reflection, and the electric component is doubled in intensity.

Since the audion is a type of detector which operates primarily on changes of potential rather than of current, the terminal connected to the end of the wire is subjected to changes of potential conforming to the signals transmitted along it, and these variations make themselves manifest in changes in potential along the ionic path which produce signals in the telephone. With the particular arrangement used, the signals were equally good with and without any earth connections to the detector.

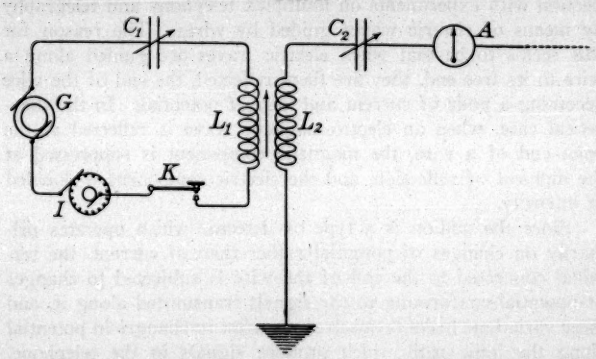
ELECTRIC WAVE TRANSMISSION ALONG A SINGLE OPEN WIRE OF A TELEPHONE CABLE.

The next experiment pertained to a No. 22 B. & S. paper insulated copper wire about seven miles long in conduit, which had a resistance of about 388 ohms. The distant end of this wire was left open. Electric waves of a length of 7500 meters, corresponding to 40,000 cycles per second, were developed by a high-frequency generator and were induced upon this line by loose inductive coupling. The circuit used is shown diagram-

matically in Fig. 1, where G is the generator of the continuous oscillations of 40,000 cycles per second; C_1 the condenser, and L_1 the coil for tuning the primary circuit to resonance with the generator period; I the interrupter; K the transmitting key; C_2 the condenser, and L_2 the coil for the corresponding tuning elements in the secondary or line; A the line ammeter. The data for a resonance curve of this line were taken and are given in the subjoined table. The graph of this data is shown in Fig. 2.

Since the frequency of 40,000 cycles per second is above audition, it is necessary, in order to transmit telegraphic signals, to insert at the transmitting end an interrupter, breaking the series of continuous waves into groups or trains of a frequency

FIG. 1.



within the limits of audition. This was done in the manner usually employed in wireless telegraphy, and the wave train period was approximately $\frac{1}{1000}$ second, giving a clear musical note.

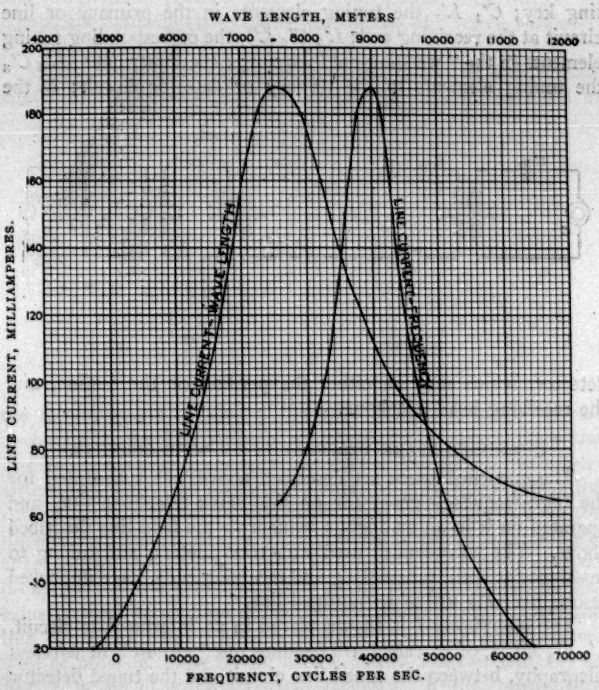
TRANSMISSION OF INAUDIBLE SIGNALS.

It is usual to insert the interrupter for the production of wave trains at the transmitting end of the line, but there are advantages in shifting this piece of apparatus to the receiving end. Accordingly, experiments were conducted to determine this point. With the interrupter shifted to the receiving end of the line, inaudible signals were sent out by making and breaking the line current of 40,000 cycles per second according to the

dots and dashes of the Morse alphabet. Signals sent out in this manner were entirely inaudible at any point along the line, and can only be interpreted at a given point by inserting an interrupter whose function is to break up the otherwise inaudible

FIG. 2.

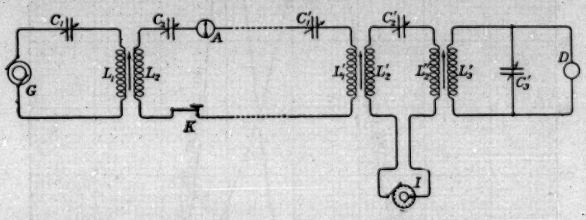
RESONANCE CURVES AT TRANSMITTING END, SINGLE WIRE OF TELEPHONE CABLE LINE, RECEIVING END OPEN, DYNAMO FREQUENCY CONSTANT AT 40,000 CYCLES PER SEC.



trains of waves, corresponding to the periods when the key is closed at the transmitting end, into groups which can be heard. This experiment was entirely successful and offers the advantage that the line itself is never permitted to carry any current of audible frequency, so that the chances of interference with

neighboring lines are diminished and there is no possibility of detecting the signals by any of the usual means. The circuit for this arrangement is given diagrammatically in Fig. 3, where G is the generator of the continuous oscillations of 40,000 cycles per second; C_1 the condenser, and L_1 the coil for tuning this primary circuit to resonance with the generator period; L_2 C_2 the corresponding tuning elements in the secondary or line circuit at the transmitting end; A the line ammeter; K the transmitting key; C'_1 L'_1 the tuning elements in the primary or line circuit at the receiving end; L'_2 C'_2 L''_2 the corresponding tuning elements in the "weeding-out" circuit; I the interrupter; L'_3 C'_3 the tuning elements in the tertiary or detector circuit; D the

FIG. 3.



detector, which may be either the perikon or the audion, and the receiving head-telephone.

QUENCHED SPARK TELEGRAPHY ON WIRE CIRCUITS.

The quenched spark set described above was substituted for the high-frequency generator on this same telephone line, and operated on it in an analogous manner to the field line described above. The wave-length used was 1000 meters, and tuning to resonance at both transmitting and receiving ends, gave improved results over the use of an untuned line.

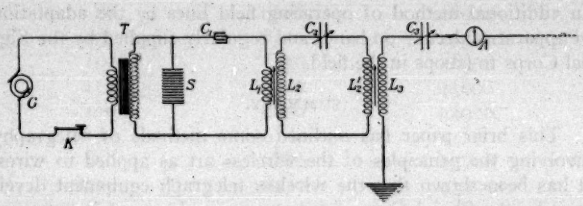
The interrupter I is shown placed in an intermediate circuit, L'_2 C'_2 L''_2 I, often called a "weeding out" circuit" in wireless telegraphy, between the tuned line circuit and the tuned detector circuit. Since this circuit has no source of electromotive force in it, the operation of the interrupter does not produce audible signals in the receiver, except when wave trains from the distant end are passing through this circuit; in other words, if the

interrupter be put directly in the line circuit, static charges on the line would produce false signals in the telephone, and if inserted in the detector circuit a similar result would occur on account of making and breaking the local battery circuit therein.

It is shown in the above experiments that the standard form of quenched spark apparatus of low power is available for use on wire circuits, and, as these sets are comparatively inexpensive and are made in portable sizes of small power, they furnish an equipment immediately available for the use of "wired-wireless" on short lines.

It has been found necessary, however, to use an intermediate circuit at the transmitting end similar to the one described at

FIG. 4.



the receiving end of Fig. 3. In case the quenched gap circuit is coupled to the line without an intermediate circuit, since the line is of comparatively high resistance, and hence not a persistent oscillator, the waves are damped out so quickly that the tuning of this circuit is extremely broad. By the use of the intermediate circuit of low resistance and also of high inductance, sometimes called a "fly-wheel" circuit, the rapidly damped oscillations in the primary circuit set up more persistent oscillations in the intermediate circuit, which latter will now force the line circuit into more persistent oscillations than would otherwise be possible. The circuit used is shown diagrammatically in Fig. 4, where G is the 500-cycle generator; K the transmitting key; T the open core transformer; S the quenched spark gap; C_1 the condenser and L_1 the coil in the primary transmitting circuit; L_2 C_2 and L'_2 are the corresponding tuning elements in the intermediate or "fly-wheel" circuit; L_3 and C_3 are the cor-

responding elements in the line circuit; and *A* is the line ammeter.

When this same line was operated as a standard Morse circuit, the superposition of the quenched spark "wired-wireless" on the same line was equally successful.

TELEGRAPHY ON WIRE CIRCUITS AT 500 CYCLES.

An experiment was tried of connecting the 500-cycle generator of the wireless set to the telephone line directly, the receiving apparatus being a low-resistance telephone of the ordinary type. With a voltage of about 110 and a series resistance of approximately 2 megohms in the line at the transmitting end, that is, with a transmitting current of about 50 micro-amperes, very loud signals were received. This simple arrangement offers an additional method of operating field lines by the adaptation of apparatus already on hand, and regularly supplied by the Signal Corps to troops in the field.

SUMMARY.

This brief paper has outlined some methods of telegraphy involving the principles of the wireless art as applied to wires. It has been shown that the wireless telegraph equipment developed by the Signal Corps for use on aëroplanes or for communicating with mobile troops in the field, can be employed to create additional telegraphic channels of communication as follows:

(*a*) The standard insulated field wire furnished to the Signal Corps, when paid out on the ground and normally operated by the standard field buzzer, may be efficiently used to transmit Morse signals by electric waves by connecting it directly or inductively to the 500-cycle generator supplied for the wireless equipment, and the signals interpreted at the receiving end of the line by the standard low-resistance telephone.

(*b*) This same wire may also be used to guide the high-frequency electric waves transmitted by the complete field wireless quenched spark sending set and received by the complete wireless receiving set with the usual detector and high-resistance telephones. This gives three well-defined and distinctly separated methods of transmitting intelligence over wires, and permits the possibility of using them either separately or in any operative

combination in accordance with the particular requirements of the case. The above results can be accomplished without the addition of a single piece of apparatus over what is already in the hands of the field companies of the Signal Corps.

DATA FOR RESONANCE CURVES OF SINGLE OPEN WIRE OF TELEPHONE CABLE.

Line Current, in milliamperes,	Wave Length, in meters,	Cycles, per second.
20	4670	64200
30	5100	58800
40	5280	56800
50	5590	53700
60	5800	51700
70	6020	49800
80	6140	48900
90	6320	47500
100	6450	46500
110	6580	45600
120	6680	44900
130	6780	44200
140	6880	43600
150	6950	43200
160	7010	42800
170	7130	42100
180	7250	41400
188	7500	40000
180	7940	37800
170	8070	37200
160	8230	36500
150	8350	35900
140	8480	35400
130	8630	34800
120	8830	34000
110	9020	33300
100	9290	32300
90	9640	31100
80	10200	29400
70	10900	27500
62	11950	25100

Repairing Metal Work by Arc Welding. (*Electr. Rly. Jour.*, xxxviii, p. 1059.)—The Pittsburgh Railways Company employs an arc-welding plant for repairing all kinds of constructional metal work, except gray iron castings. Carbon electrodes are generally used, but for such work as welding sheet steel on a gearcase an electrode of cold-rolled steel is used, the melting of which provides the required additional metal. The flux used for welding consists of 17 parts borax, 1½ parts brown iron oxide, and 1½ parts red iron oxide. It is stated that during the first week of use about $237 was saved, all the necessary material, except the flux, being taken from the scrap heap. The welding current is furnished by an old G. E. booster, consisting of a 30-horsepower shunt motor and a 60-volt 300-ampere generator. The shunt field of the booster is directly excited from the trolley circuit. The grid resistances, which are inserted in the series field in series with the armature, can be varied from 0.02 to 0.045 ohm, according to the current required.

The Law of Conservation as Applied to Illumination Calculations. A. S. MCALLISTER. (*Amer. Ill. Engin. Soc. Trans.*, vi, 703.)—The law of conservation of flux is: that the value of the luminous flux is neither decreased nor increased until transformed according to the well-established laws of nature. In so far as the so-called cosine and inverse square laws are concerned, it is absolutely accurate to calculate the flux produced by the source by taking the sum of the fluxes absorbed by the medium illuminated. The mathematical relations between flux and solid angle are worked out, and line, plane, and spherical surface illumination formulæ are obtained. Curves are given of the illumination on equilux spheres and on horizontal and vertical planes.

Relation of Chemical Composition to Calorific Power in Wood, Peat, etc. H. C. SHERMAN AND C. G. AMEND. (*School of Mines Quart.*, xxxiii, 30.)—Eight substances—chestnut wood chips, raw and leached, hemlock tan, raw and leached, leached oak tan, bagasse, oil cake and peat—were subjected to ultimate analysis, and their calorific power was determined directly in a bomb calorimeter. The values calculated by Dulong's formula,

$$X = 8080C + 34{,}500\,(H - \tfrac{1}{8}O) + 2220\,S,$$

were seriously low in all cases; whereas when calculated according to Walker's formula,

$$X = 8080\,(C - \tfrac{3}{4}O) + 34{,}500\,H + 2220\,S,$$

the results were high, but were a fair approximation to the true values. In the case of seven lignites, the calculated results were nearer correct when calculated by Walker's method than by Dulong's.

BITUMINOUS ROADS AND PAVEMENTS AND THEIR MATERIALS OF CONSTRUCTION.[1]

BY

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THE subject upon which I have been invited to speak is so broad that a large sized text-book would be required to cover, even in abstract form, the information that has so far been obtained by engineers and chemists engaged in bituminous road and paving work. It is evident, therefore, that the present discussion must be limited to a few fundamental principles if the entire subject is to be covered.

Notwithstanding the enormous amount of bituminous road and paving work that has been done in this country, the majority of highway engineers to-day are far from feeling satisfied that they can successfully meet in an economical manner the problems which modern conditions have imposed. To a great extent this is due to their lack of information regarding the physical and chemical characteristics of the materials which they are obliged to use, and to a reluctance on the part of many municipalities to incur the expense of expert inspection of these materials. It is safe to say that no type of work requires more careful nor more constant inspection than that involving the use of bituminous road and paving materials, and until such inspection is generally adopted the use of these products will never pass beyond the experimental stage. The reason for this must be apparent when the widely-varying nature of the bitumens themselves is considered.

No sharp distinction can be made between the terms roads and pavements. This is especially true at the present time, owing to the fact that many materials of construction are common to both, and in suburban roads in particular the methods of construction often approach very closely, or are identical with, the methods of constructing certain types of city pavements. In general, however, roads may be considered as highways, improved

[1] Presented at the meeting of the Mechanical and Engineering Section, held February 29, 1912.

or unimproved, which mainly occur in rural and suburban districts, and pavements as highways occurring mainly in cities and towns. Roads are usually constructed of earth, gravel, or broken stone, with or without the addition of special binding material. In the more advanced types but little attention is paid to grading the aggregate. Pavements, on the other hand, are constructed of sand or broken stone bound with an hydraulic or bituminous cement and often of a mixture of three or four constituents carefully graded and proportioned before mixing. In addition, regular sets of brick, stone block, asphalt block, and bituminized or creosoted wood blocks are also employed. At the present time great variations in methods as well as materials of construction exist, and because of this fact absolute standards which will successfully meet all conditions are an impossibility. The problems encountered in road and paving construction are so numerous and so involved that the services of experts who have specialized in this field have come to be almost a matter of absolute necessity where work of any magnitude is undertaken except in a purely experimental manner. And even where the work is of an experimental nature expert advice and inspection are necessary to obtain information of greatest value, upon which future work may be based.

Bituminous roads and pavements may be conveniently divided into seven groups: (1) bituminous earth roads, (2) bituminous gravel roads, (3) bituminous macadam roads, (4) bituminous concrete pavements, (5) sheet asphalt pavements, (6) asphalt block, and (7) bituminized wood block pavements. All of these groups are sharply defined with the exception of the bituminous macadam and bituminous concrete, which overlap each other according to the method and degree of refinement used in construction. Bituminous earth, gravel, and broken stone roads may be either constructed in such manner that the bituminous binder is incorporated in the road proper, or only a surface application of the bitumen may be given to the otherwise completed road. In the last four types bitumen is always incorporated with at least a portion of the paving material, and usually before placing it. Whether in surface treatment or construction, selection can be made from a great variety of bituminous materials, and these materials may be applied or used according to many different methods.

The selection and use of bituminous materials for the types of roads and pavements previously mentioned may best be discussed after considering the characteristics of the bitumens themselves.

In the broadest sense bitumens may be defined as mixtures of native or pyrogenous hydrocarbons and their derivatives, which may be gases, liquids, viscous liquids, or solids. If solids, they soften more or less readily upon the application of heat and are soluble in certain organic solvents. They may be conveniently divided into two main classes: (1) native bitumens and (2) artificial bitumens. Native bitumens, as their name implies, occur in nature, and often contain impurities, such as water, clay, silt, sand and extraneous organic or vegetable matter. Those of interest as road materials are petroleums, malthas, asphalts, and other solid products of an asphaltic nature, such as Gilsonite and Grahamite. Artificial bitumens are distillates and residues produced by the partial or fractional distillation of bitumens, pyrobitumens, and other organic materials, such as wood or bone. Manufactured petroleum residuums, oil asphalts, asphaltic cements, coal tars, water-gas tars, and tar distillates are the most important members of this class from the stand-point of road and paving work.

Both crude native and artificial bitumens are almost invariably refined before they are used in highway treatment or construction. The refining process may consist in a separation of some of the constituents present, either by sedimentation or distillation. A third process, known as fluxing, is also employed to a large extent in the preparation of the finished product. With few exceptions, crude bitumens contain water, and the crude native products carry extraneous mineral and organic matter as well. If the material is sufficiently fluid, as in the case of many crude petroleums and tars, much of the water may be removed by natural separation in large storage tanks or wells. Here the water gradually collects at the bottom where petroleums are stored, and also mineral matter if it is present. In the case of tars the water rises to the top, owing to the greater density of such materials. If the crude material is extremely viscous or semi-solid, heat may be required to effect the separation. Native asphalts are thus refined by heating them in large tanks or kettles until fluid, when the water and extraneous organic matter col-

lect at the top and are skimmed off, while the mineral impurities collect at the bottom.

In the manufacture of dust preventives and binders from bitumens, consistency is one of the most important physical properties to be considered, and this property can be controlled by distillation or fluxing. Thus a fluid petroleum or tar may be brought to any desired degree of solidity by distilling off the proper portion of the more volatile constituents. If the distillation is accompanied by blowing air through the hot material, the desired degree of solidification may be brought about at a lower temperature than by straight distillation and the yield of residue increased, but such effect is produced by certain chemical changes in the material proper, and not by merely removing the more volatile products. This method is known as the blowing process, and the materials produced are said to be blown products. They are characteristically short or non-ductile.

Fluxing consists in mixing or combining a hard or solid bitumen with one that is more fluid, called the flux. This combination is usually facilitated by the application of heat and mechanical agitation. Fluxing may serve one of two purposes: a hard bitumen may be softened to the desired consistency by the addition of a fluid bitumen, or a viscous bitumen may be reinforced or hardened by the addition of a solid bitumen. Thus it is customary to soften a refined native asphalt with a fluid petroleum residuum and also to reinforce very viscous blown petroleum residuums with such products as Gilsonite, which are hard and solid.

The following diagram gives a graphic representation of the principal types of bituminous road and paving materials as produced by the processes mentioned, also of products formed simultaneously with their manufacture.

It will be noted that the crude materials are divided into three general classes—petroleums, asphalts, and tars—which are all subjected to the process of sedimentation before further use, in order to remove water and other impurities in so far as possible. Distillation is the second process involved in the preparations of petroleum and tar products, and in each case two classes of products are formed—distillates and residues. This distillation results mainly in a fractionation of the material, and the more volatile constituents or distillates are thus separated from

the less volatile residues. When fractional distillation is employed the distillates are oils or greases and possess no binding value. The true binding constituents, if present, are always to be found in the residues, and these residues are used to a great extent as binders for road and paving work.

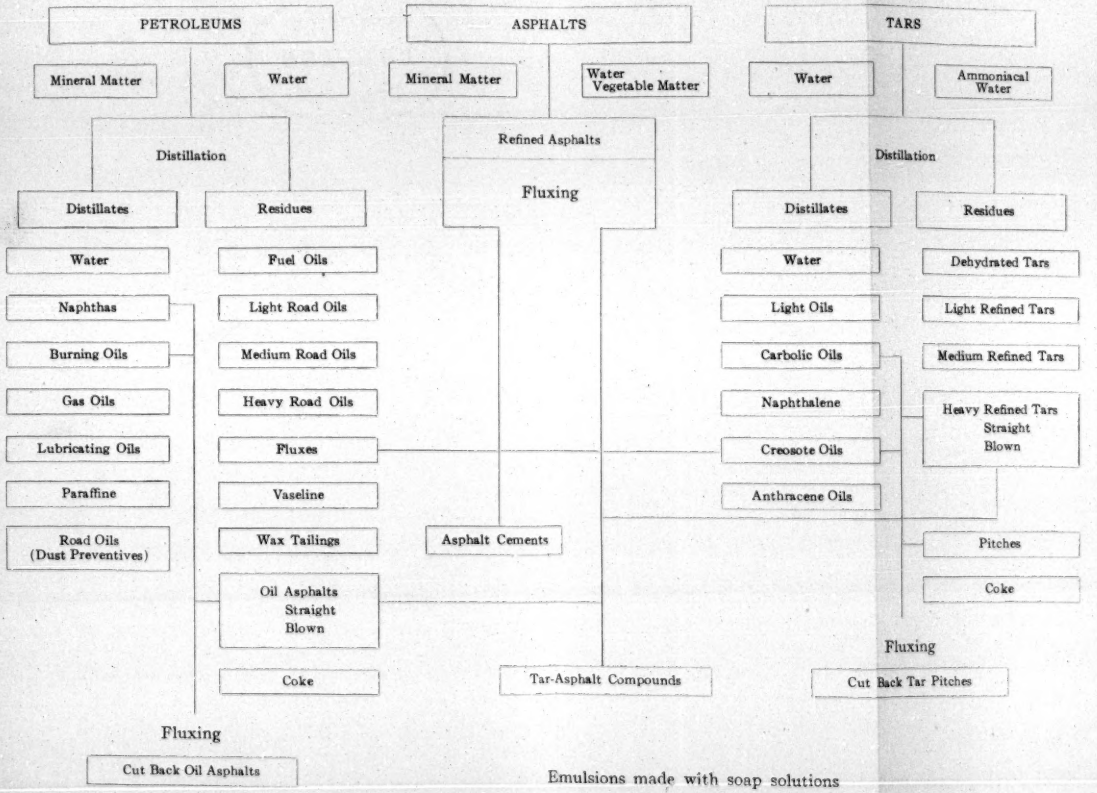
As previously stated, the consistency of a residue may be controlled by the quantity of distillate removed. Sometimes the residue, while otherwise satisfactory, is harder than can be readily employed according to a given method of construction. For instance, an oil asphalt or heavy refined tar, while suitable for the preparation of a bituminous concrete, cannot be mixed with cold stone. When this is so the material is sometimes fluxed with one of the lighter distillates which have previously been removed, and the resulting product is said to be cut back. The oil or tar residue is thus brought to any desired degree of fluidity necessary to facilitate cold mixing, and the distillate is expected to act only as a temporary flux. If sufficiently volatile, it will, in the course of time, evaporate and leave the original residue as the permanent binding material.

Refined asphalts and other solid native bitumens of an asphaltic nature are often too hard for road or paving work. Permanent fluxes, such as the fluid non-volatile petroleum residues, are therefore incorporated with them to produce asphalt cements of desired consistency. Various combinations of petroleum residuums with tar products may also be made with the formation of what are known as tar-asphalt compounds. Emulsions may be produced from nearly any of the bitumens used in road and paving work by incorporating them with soap solutions in one way or another.

While distillation at comparatively moderate temperatures usually results in fractionally separating the constituents already present in a bitumen, if it is carried beyond a certain point the compounds remaining in the residue may be altered chemically. This is caused by a cracking or breaking down of certain of the constituents into products which did not exist in the original material, and the general character of the material is therefore altered. If distillation is pushed to the limit, a complete change in the residue is effected and coke is formed. In this case the process is said to be destructive. The two extreme forms of distillation are therefore known as fractional distillation and

PREPARATION OF BITUMINOUS MATERIALS.

SEDIMENTATION



Emulsions made with soap solutions

destructive distillation. An intermediate form where chemical changes take place without the production of coke is known as cracking. It is evident that the method of distilling a bitumen will largely control the ultimate character of both distillate and residue. As applied to bitumens, the process of cracking and destructive distillation results in the formation of undesirable residues from the standpoint of their use in road and paving work.

This point may be illustrated by comparison with the very common operation of making candy from a solution of sugar in water. At first the sugar solution is a comparatively thin liquid possessing very little adhesiveness. As it is boiled, however, a portion of the water is driven off or fractionally separated and the residue gradually becomes more viscous and sticky. The formation of a syrup is thus entirely comparable with the production of a thick, viscous road oil or road tar. In the case of the sugar solution, if boiling is continued a little further more water is removed, and if the residue is allowed to cool a sticky taffy is produced which can be compared with the oil asphalts and soft tar pitches. If the solution is boiled beyond the taffy stage more water is removed and brittle candy is formed, which corresponds to the harder pitches from bitumen distillation. Now up to this point the inherent adhesiveness of the sugar solution has not been injured, and if the brittle candy is dissolved in a little water a sticky syrup will be produced. This would represent the cutting-back process before mentioned. If, however, the sugar solution is not removed from the fire at the brittle candy stage certain chemical changes begin to take place. First the solution darkens very decidedly with the formation of caramel, and the odor of burnt sugar is noticed in the vapors given off. Evidently something besides water is being removed. Sugar itself will not distil unaltered, and the product other than water which is driven off has been formed by a chemical breaking down of the sugar molecules. Here we have an example of cracking. If the solution remains much longer on the stove the entire mass swells up, intumesces, and gives off an acrid odor, and an examination of the residue when cold will show it to be black, brittle, and powdery. It has almost entirely lost its property of forming a syrup when mixed with water, and, in fact, the greater portion will not even dissolve in water, but floats on the

surface as a black deposit. In other words, its binding value has been seriously injured. If the mass is still further heated, tarry vapors are produced and only coke remains in the container. The final operation has been destructive.

In the preparation of petroleum road and paving binders, only those oils which produce residues similar to the native asphalts are of value. There are two distinct types of crude petroleum, one of which contains a greasy base or residue and the other a sticky base. They are known, respectively, as paraffin and asphaltic petroleums. Intermediate varieties which partake of the nature of both and contain a mixed base are known as semi-asphaltic petroleums. Paraffin petroleums are chemically more stable than the asphaltic petroleums, and are therefore less likely to change in character under service conditions. While these residues have little adhesive value, if sufficiently fluid they may make admirable permanent fluxes. A fluid asphaltic petroleum residue, on the other hand, may make an undesirable permanent flux, owing to its tendency to harden under atmospheric conditions and thereby to increase the hardness of an asphaltic cement beyond the proper limit for the work in which it is used. The proper selection of a flux for the preparation of an asphaltic cement is consequently a very important matter. This is also true of cut-back products, in which the flux should be either chemically unstable or readily volatile.

Certain intermediate native products, lying between the petroleums and asphalts, which are known as malthas, exhibit many of the properties of cut-back oil asphalts. They contain an asphaltic base, certain volatile constituents, and a scarcity of intermediate oils. When the lighter oils evaporate under natural conditions a semi-solid residue or asphalt is left. When malthas occur impregnating sandstone, the aggregate is termed rock asphalt. Rock asphalts have been used to a considerable extent in road and paving work.

There is almost as great a variety of solid native bitumens as petroleums. In fact, these products may, for all practical purposes, be considered as naturally produced petroleum residuums. They therefore range from almost pure paraffin compounds to asphaltic compounds. The latter only are suitable for the preparation of road and paving materials. They are, as a rule, too hard to be used for this purpose in their natural condi-

tion, and have to be fluxed to desired consistency. Under the native asphalts, such products as Gilsonite, Grahamite, and other solid native bitumens of an asphaltic nature may be grouped.

While petroleums, malthas, and the solid native bitumens are all closely related and many of them contain identical constituents, tars are an entirely different class of bitumens. They are artificial distillates produced by the destructive distillation of organic matter, such as coal, wood, bone, oil, etc. Those of special interest from the stand-point of road and paving work are produced from bituminous coal, and from gas oils which are themselves fractional distillates of petroleum. Unlike the distillates from fractional distillation, those produced by destructive distillation often possess a very considerable amount of inherent binding value. Thus the gas oils are, as a rule, essentially greasy, but if they are subjected to a peculiar process of cracking, as in the manufacture of carburetted water gas, the tar distillates which are produced may afterwards be fractionally distilled to produce characteristically adhesive residues or tar pitches.

Coal tar is a by-product of the manufacture of illuminating gas or coke from coal, and tar produced as a by-product from gas oils in the manufacture of carburetted water gas is known as water-gas tar. Although originating from two entirely different sources, they have many properties in common, and to a large extent carry identical constituents. In the crude state they always carry a considerable percentage of water, which in the case of coal tars is ammoniacal. As they are distillates, practically no mineral matter is present, but they contain more or less suspended organic matter, not bitumen, which is commonly called free carbon. The water may, to a large extent, be removed by sedimentation, and this removal is completed in the first stages of fractional distillation. Free carbon, however, persistently remains in the tar body and cannot be removed except by filtration. This is seldom if ever done in the manufacture of road and paving materials.

Coal tars may be divided into two classes, known as gas-house tars and coke-oven tars. The former, as a rule, contain a much higher percentage of free carbon than the latter, and in certain respects are less desirable for the manufacture of road binders. Water-gas tars contain only a very small percentage of

free carbon. In 1908 about 101 million gallons of coal tar were produced in this country, nearly 43 million of which were coke-oven tars. In 1910 over 66 million gallons of coke-oven tar were produced and recovered. Our possible annual supply of this type of bitumen is, however, far in excess of this figure, for it has been estimated that the enormous amount of 500 million gallons of coke-oven tars was lost during 1910, through the use of non-recovery or bee-hive ovens in which the vapors are wastefully allowed to burn upon being set free from the coal. The value of the tar thus lost amounts approximately to $12,000,000 annually.

In the preparation of tar binders the method of distillation conforms quite closely to that followed in the manufacture of petroleum binders. For a given type of construction, however, a much softer tar residue is prepared than in the case of petroleum. This is due to the fact that the harder tar residues are much more susceptible to temperature changes than the petroleum or asphalt preparations of similar consistency, and are therefore apt to be more brittle in cold weather. A softer consistency for tar products is allowable because of their greater adhesiveness and binding value, and it is further advisable because tar binders set up or harden more rapidly through loss by volatilization or certain chemical changes which the tar undergoes on exposure to service conditions. Attempts to bring these peculiar characteristics of tars under more perfect control have been made by fluxing or incorporating them with certain petroleum products. The resulting mixtures are called tar-asphalt compounds. While the possibilities of such mixtures are great, and encouraging results have in certain cases attended their use in road construction, there is much yet to be learned regarding them. Unless carefully made, with just the proper grades and proportions of each, the combination of tar and petroleum products to form a satisfactory road material is by no means assured, and a considerable amount of research will be required to perfect the tar-asphalt compounds. Frequent failures have resulted from the indiscriminate mixture of these materials by engineers not familiar with the physical and chemical properties of each. In the author's opinion, the fundamental cause of these failures is due to the fact that, while some of the lighter constituents of tars are good fluxes for petroleum bases, petroleum oils are poor fluxes

for tar residues, and often act as precipitants of these bases with the formation of a crumbly, non-adhesive mixture.

One of the constituents of tars which is of considerable interest in connection with road and paving materials is naphthalene. This product is found both in the distillates and in the tar residues. It is a white crystalline substance, readily volatile, and, although solid at ordinary temperatures, it has the property of acting as a flux for the solid tar pitches. Thus a combination of two solid bodies may be made to produce a fluid mixture. It would seem that the volatilization of naphthalene from tar residues might be largely responsible for their rapid hardening under service conditions. Naphthalene also occurs in the tar distillates used for creosoting wood block. So far as the author is aware, except for the purpose of cutting back residues, tar distillates are only of value in the road and paving industries for the purpose of impregnating and water-proofing wood block. They are seldom if ever used for road treatment, as they exhibit no binding value and have but few of the characteristics requisite for a good dust preventive. Even when used in connection with wood it is a question as to whether their quality is not improved by the addition of tar residues containing low percentages of free carbon.

Having in a general way considered the preparation and characteristic properties of the bitumens used in road and paving work, their application for this purpose may be taken up. In the present paper it is hardly practicable to describe in detail the various methods of applying bitumens and of constructing bituminous roads and pavements. What results are to be expected from the use of the different types of bitumens may, however, be briefly considered.

The use of bitumens in the treatment and construction of earth roads was first tried for the purpose of reducing the annoyance and damage caused by road dust in localities where protracted spells of dry weather were of frequent occurrence. Most of this work has been carried on in the State of California, where crude native asphaltic oils of local occurrence were first applied to the road surface. The results were so successful, in so far as laying the dust was concerned, that after the first experiment had been made in 1894 the use of crude oil for this purpose advanced quite rapidly. From this work it was soon learned that so long

as the road was hard and dry it could be made dustless for a considerable length of time by a single application of oil. In rainy weather, however, the road became saturated with water, and the oiled crust broke up under traffic, producing a disagreeable mud. When the road again dried out, the dust-laying effect of the oil was to a great extent destroyed, owing to the destruction of the crust. Because of this fact, attempts were made to construct oil earth roads by incorporating the oil with the earth to a depth of five or six inches. This was accomplished by first plowing up and harrowing the road to the required depth, then applying the oil, and afterwards mixing it with the earth and consolidating the mixture by means of an ingenious device known as the sheep's foot or tamping roller. Roads so constructed were found to be almost permanently dustless, but their capacity for bearing loads was much lessened as compared with the hard dry earth, and their tractive resistance was greatly increased. The development of such roads up to the present time has shown them to be far from satisfactory under heavy hauling traffic, and when constructed in the eastern section of the United States, and, in fact, almost anywhere except in California, they have almost invariably proved failures.

There are two fundamental reasons for this lack of success, and one of these reasons is an underlying principle which has long been recognized in the construction of sheet asphalt pavements. It is, that in order to produce a satisfactory wearing surface from a mixture of bitumen and a finely-divided mineral aggregate containing particles no larger than sand grains it is necessary that the aggregate be carefully graded and that the bitumen be a semi-solid having very definite consistency limits. In other words, the tendency of the particles of a finely-divided aggregate to displacement under traffic conditions must be overcome by first making the aggregate as dense as possible, and then holding the particles together by cementing them with a tough and fairly hard bituminous binder. This is the key to the situation as regards bituminous earth roads, and because of the difficulties in meeting these requirements the outlook for this type of road is not exceedingly promising. Even if the grading of the mineral matter could be assured, the thorough incorporation of unheated earth with a melted bitumen, which congeals upon coming in contact with it, cannot be accomplished, and a more

fluid product will not produce the requisite stability. The only reason that partial success has attended such work in California is that the local petroleums are highly asphaltic and exhibit a tendency to harden rapidly upon exposure to atmospheric conditions. The absolute failures in the East are due, first of all, to the above-mentioned cause, and, secondly, to the fact that the oils used were only semi-asphaltic and possessed neither the binding value nor the tendency to harden which the California oils exhibit. As a result, these roads had little bearing capacity and rutted badly under traffic. In wet weather water was ground into the oiled earth, with which it emulsified to produce an obnoxious greasy mud to the full depth of the road. Under these conditions even the dust-laying effect of the oil soon disappeared.

With regard to bituminous gravel roads little need be said, as they are the connecting link between the bituminous earth and bituminous macadam types and partake to a great extent of the nature of both. In general, the surface treatment of gravel roads with bitumens gives more promise of success than the use of these materials in construction. Well-compacted gravel has considerable inherent stability or capacity for carrying loads without suffering displacement. A bituminous mat or crust formed on the surface of a gravel road does not tend, therefore, to break through under traffic, as in the case of earth roads. Most gravel, however, contains a large proportion of rounded water-worn pebbles which do not interlock, and, when mixed with a bituminous binder, tend to slide over one another under pressure. Unless the gravel contains a certain proportion of coarse, angular sand grains which operate to reduce such movement, the bituminous-constructed gravel road is not as apt to give satisfaction as the bituminous macadam.

Before considering the bituminous macadam road it may be well to review briefly the reason why it has become necessary, in many localities, to modify the old macadam type of construction. The principal cause is generally admitted to be a class of traffic that has within the past ten years become quite common, but which was unknown in the days of Macadam, and for which the road that bears his name was never devised. The roads of to-day are called upon to meet entirely different conditions from those formerly encountered, owing to the introduction and rapid

adoption of the automobile. Had not this new class of traffic appeared, the ordinary macadam would still be a successful type of road for country and suburban traffic, as it is well adapted to meet the conditions imposed upon it by horse-drawn, steel-tired vehicles. It has been found, however, that no ordinary water-bound macadam is capable of withstanding, for any length of time, the action of excessive automobile traffic, which tends to denude the road of all its rock dust, thus destroying the bond of the wearing surface, and then to pry loose the larger fragments of stone beneath, and so cause ravelling and disintegration. To prevent this action, recourse has been had to treating old road surfaces with bituminous materials so as to prevent the removal of dust and at the same time bind and hold in place the fragments of broken stone which constitute the body of the road.

For the treatment of old road surfaces fluid petroleum and tar residues, and also certain petroleum distillates, have been extensively used. The latter serve as dust preventives only, and in no sense as road binders, although, by moistening or oiling the dust particles on a road, they prevent to a great extent their removal by motor traffic and thus prevent the road from rapid disintegration. This effect is but temporary, and on heavily-travelled roads rather frequent applications are required. Considerable care has to be exercised to keep the rate of application within proper limits, for if an excess of these oils is used they act as lubricants for the larger stone particles and destroy the natural binding value of the rock dust, thus hastening the disintegration of the road. Moreover, an excess will produce an oily disagreeable mud in wet weather. The same is true of the more fluid, non-volatile petroleum residuums. All of the bituminous materials which are merely dust preventives can be applied cold by means of a sprinkler.

The selection and use of viscous petroleum and tar residues which are expected to act as binders, in addition to being dust preventives, require considerable judgment, and best results can only be secured by purchasing these materials under specifications and then having them systematically examined for conformity with specifications. Such products have been termed semi-permanent binders. They are employed for the purpose of forming a bituminous cushion or mat over the road surface, thus protecting it from wear. They are applied by means of specially-con-

structed distributers, either hot or cold and with or without pressure, according to their viscosity and the desired rate of application. If they do not contain a good binding base which becomes available under service conditions they are apt to prove most unsatisfactory. Even when derived from the better types of bitumens, careful selection should be made with regard to the traffic which they will have to meet.

Unlike the plain macadam road, a bitumen-surfaced macadam is less injured by motor vehicles than by horse traffic. In fact, the former class of traffic is, under most conditions, actually beneficial to a bituminous surface cushion, and were it not for the fact that mixed traffic had to be cared for, the problem of protecting our roads from the destructive action of automobiles would be easily solved. When a road is subjected to any considerable amount of heavy teaming traffic, however, the heavily-loaded steel-tired wheel and the iron-shod horse's hoofs cut through the surface mat and cause rapid disintegration. If motor traffic is equal to or greater than the horse-drawn traffic, the cuts and abrasions of the bituminous mat caused by the latter may be ironed out as fast as formed by the passage of soft rubber tires, but where the conditions are reversed the injurious action of the horse-drawn traffic is soon made apparent, especially on narrow roads during cold, rainy weather. In order to determine what material is best suited for application to the surface of a given road it is necessary to know the volume of traffic to which the road is subjected in bad weather; the proportion of horse-drawn to motor vehicles during bad weather; and the character of both classes of traffic during bad weather. Under certain conditions no form of purely surface treatment will prove satisfactory. In such cases the use of a bituminous binder during construction may be necessary.

There are two general methods of constructing bituminous macadam roads which have been largely followed in this country, one known as the penetration method and the other as the mixing method. In both it is usually considered sufficient to incorporate the bitumen with only the upper two or three inches of broken stone constituting what is known as the wearing course. The foundation may be constructed as in ordinary macadam work, but greater attention should be paid to making this course more dense and less subject to movement under traffic.

Many failures have resulted from poor foundations, which have been wrongly attributed to the use of inferior bitumens, and it is the author's conviction that substitution of Portland cement concrete foundations for the old type of broken stone foundation will prove in many cases the most satisfactory and ultimately economical procedure.

In the penetration method of construction the wearing course of broken stone is placed upon the foundation to a depth of about three inches and partially compacted by rolling before the bitumen is applied. The size of the stones should vary according to the type of rock used. For a hard rock, such as trap, material varying from 1¼ inches to ½ inch in diameter is suitable, but when a rather soft limestone is used a coarser grade may be required. After the stone has been partially compacted, hot bitumen is distributed over the road at the rate of about 1½ gallons to the square yard. Clean ½-inch stone chips are then spread over the surface in sufficient quantity to fill the surface voids and the road rolled until firm. A paint coat of the hot bitumen should then be applied and the road finished off by rolling in another coat of screenings. Application of the hot bitumen may be made either by means of pouring pots or mechanical distributers.

In the mixing method the wearing course of crushed rock is mixed with the proper proportion of hot bitumen before it is placed on the foundation. Sometimes the aggregate itself is heated before mixing, and sometimes it is used cold. The mixing may be accomplished either by hand labor or by machinery. After the bitumen-coated stone has been laid to the desired depth it is rolled either with or without the addition of a thin layer of ½-inch stone chips free from dust. It is finished off with a coat of bitumen and chips as in the penetration method. But little attention is paid to grading the aggregate which is mixed, and usually a single grade of ordinary commercial crushed stone is used. Mechanical mixing, when properly conducted, is preferable to hand mixing, and with the recent development in small portable mixers which warm or heat the stone before mixing, very satisfactory work can be accomplished. Heating the stone on sheet-iron plates over open fires has proven to be bad practice, as there is great danger of overheating a portion of the stone and thus ruining the bituminous binder.

The selection of a suitable binder for bituminous macadam construction is a most important matter, requiring some skill and judgment. There is no one best product for all bituminous macadam roads, and selection must be governed by a number of conditions. The principal factors to be considered are: (1) the physical characteristics of the stone which is to be used; (2) the desired method of applying the bituminous binder, *i.e.*, whether the material is to be applied cold or hot and by means of a mechanical distributer, with or without pressure, by pouring from buckets, or as a prepared mixture with the road material, and in the latter case it is also necessary to know in advance whether or not the stone itself is to be heated; (3) the quantity and character of traffic to which the road will be subjected; (4) climatic conditions; (5) the cost of bituminous material; and (6) the probable cost of application. The materials from which selection may be made are oil asphalts, fluxed native asphalts, heavy refined coal tars, cut-back oil asphalts, and tar-asphalt compounds. When the type of material is finally chosen, its physical and chemical properties should be covered by specifications. Sometimes it is advisable to make use of two grades of binder, one for incorporation in the body of a road and one for use as a paint coat. Thus under certain conditions where horse-drawn traffic is heavy it may be well to use a heavy refined tar for the wearing course and an oil asphalt for a paint coat. High carbon tars should never be used for paint coats, and fluid cut-back products, as well as certain grades of oil asphalts, are also unsatisfactory for this purpose, where horse-drawn traffic is heavy.

Bituminous concrete pavements in many respects resemble the bituminous macadam built according to the mixing method. The aggregate composing the wearing course is, however, more carefully graded so as to increase its density to a considerable extent and reduce the voids upon compaction. At least two sizes of commercial crushed rock are used, or else a single size is combined with sand in such proportions that the desired result is secured. The aggregate is almost always heated before mixing it with the bituminous binder, and the binder is usually of semi-solid consistency, approaching that of asphalt cements such as are used in the construction of sheet asphalt pavements. When these refinements of construction are employed in the prepara-

tion of the wearing surface much care should be exercised in preparing a suitable foundation, for the failure of a foundation in such pavements is apt to prove costly. Portland cement concrete should be employed in most instances. Such wide variations exist in the specific gravity of both aggregates and bitumens which may be used in this type of pavement that it is never safe to rely on weight relations in proportioning the constituents unless their volume relations are first ascertained. The actual bitumen content of the bituminous binder should also be taken into account when preparing the mix. These points may be illustrated by considering what the volume relation between bitumen and aggregate would be for two possible mixtures containing six per cent. by weight of bituminous binder. Thus the combination of a blown oil asphalt, reinforced with Gilsonite, with an aggregate of high gravity might amount to 26 gallons of bitumen per cubic yard of aggregate, while the combination of a heavy, refined coal tar with an aggregate of low specific gravity might amount to only 12 gallons of bitumen per cubic yard of aggregate.

The construction of sheet asphalt pavements requires perhaps more careful inspection of materials than any other type of road or pavement so far considered. While in the bituminous macadam and bituminous concrete construction bitumens with a wide range of consistency may be satisfactorily employed if properly selected, the same is not true of sheet asphalt. The reason for this lies in the fact that the aggregate of the former possesses considerable inherent stability, and without a binder of any sort would suffer comparatively slight displacement under localized compression if first properly compacted. The wearing surface of a sheet asphalt pavement, on the other hand, consists of a finely-divided aggregate which is largely dependent upon the bituminous binder, so far as its resistance to displacement under pressure is concerned.

The most common type of sheet asphalt pavement consists of three courses: (1) a Portland cement concrete foundation, (2) an intermediate course of crushed rock mixed with a bituminous binder known as the binder course, and (3) a wearing course composed of a mixture of sand, limestone dust or Portland cement and an asphalt cement or oil asphalt. Various modifications of construction are allowable under certain con-

ditions. Thus a well-compacted old macadam road or an old stone block pavement may sometimes be made to serve as a foundation. Where traffic is light the binder course is sometimes omitted, and the wearing course is placed directly upon a concrete foundation. When the binder course is used it may be either of the open or closed type, and so on. It is hardly possible, in the present paper, to consider the relative merits of all of the modifications of construction which may be enumerated. The wearing course may, however, be briefly discussed.

In the first place, it is absolutely essential that the aggregate of the wearing course be carefully graded so as to produce under compaction a dense mass as free as possible from voids. This is a matter which requires the most constant supervision, owing to unavoidable variations in different lots of sand obtained from the same source. Sometimes it is necessary to combine two or more sands in order to obtain the proper grading, and the proportion of limestone dust or Portland cement which serves as a filler must be increased or decreased according to variations in the sand. The proportion of bitumen which is added must also be watched, and frequent examinations of the mix must be made to determine if the proportions have been correctly made. The physical and chemical characteristics of the asphalt cement must also be kept under perfect control, and this can only be done by constant and expert inspection. Innumerable costly failures have resulted from a lack of such inspection.

The preparation of an asphalt surface mixture or topping, as it is more often called, is carried on at an asphalt plant. Quite frequently the asphalt cement is also prepared here by fluxing a refined native asphalt with a petroleum residuum flux. The asphalt is first melted in a specially-constructed melting tank, preferably heated by steam and equipped with perforated pipes for air agitation. The proper proportion of hot flux, which has previously been determined, is then run into the melted asphalt and the two thoroughly mixed until a homogeneous product has been prepared. The consistency of the asphalt cement is then determined to see that it is suitable for the work to be done. If satisfactory it is ready to be mixed with the mineral aggregate. This aggregate, composed of a mixture of selected sand, is first dried and heated in a revolving cylindrical drum, from which it is discharged and conveyed to the mixer after adding the

proper proportion of filler. Here a batch is measured out and run into the mixer, after which the proper amount of the melted asphalt cement is added and thoroughly mixed with the aggregate by means of two sets of revolving metal blades operating in opposite directions. At all stages of the mixing process it is necessary to control carefully the temperature of both bitumen and aggregate so as not to harden or otherwise injure the former. The prepared mix must, however, be sufficiently hot to be readily spread upon the street, where it is laid to the required depth and compacted by means of a tandem roller.

Little need be said in the present paper regarding asphalt block or creosoted wood block. The former is composed of a mixture somewhat similar to the sheet asphalt topping, but containing crushed rock, a portion of which is considerably coarser than the coarsest sand of an asphalt topping. The bitumen is also of harder consistency and the mixture is subjected to considerable pressure in order to produce a block which will withstand handling and transportation without breaking. Creosoted wood blocks are usually made from long-leaf yellow pine or Douglas fir. They are first sterilized by steaming, then placed in a partial vacuum to remove the moisture and gases which they may contain, after which the desired amount of creosoting oil is forced into them under pressure. The proper grade and character of creosoting oils suitable for wood-block treatment is at present an open question among engineers and chemists, some preferring a pure coal-tar distillate and others claiming that the presence of a small amount of residue in the distillate is a rather desirable feature. Lack of knowledge on the part of engineers regarding the characteristic properties of distillates and residues has often resulted in the preparation of specifications conformity with which would make it impossible to supply the product called for. Thus specifications stating that the oil must be a pure distillate are often drawn up in such form that all pure distillates are excluded and only mixtures of distillates and residues can be made to fulfil the various clauses of the specifications.

So much has been said concerning the necessity for expert inspection of materials used in bituminous road and paving work that a brief description of some of the more common laboratory methods of examination may not be out of place. There are four main purposes for which bitumens may be used in highway

treatment or construction: (1) as dust preventives, (2) as binders for coarse aggregates, (3) as binders for fine aggregates, and (4) as preservatives. The method of examination should be varied according to the type of material and the purpose for and manner in which it is to be used. The more common tests may be divided into six groups: (1) specific gravity; (2) consistency; (3) flash point, volatilization, and distillation; (4) total bitumen; (5) the action of selective solvents, and (6) miscellaneous. The first of these need not be discussed other than to state that the specific gravity of a material is often a valuable means of identifying it when taken in connection with certain other tests.

There are five commonly used tests for determining the consistency of bitumens: (1) viscosity, (2) float test, (3) penetration test, (4) ductility, and (5) melting point. The viscosity test is applied to fluid bitumens and usually consists in determining the length of time required for a measured volume of the material to flow through a tube of known diameter and length under standard conditions of temperature and pressure. The results are expressed in terms of the viscosity of water under the same conditions, or as specific viscosity. The float test is a measure of the time required for a plug of the bitumen to soften sufficiently to allow water to displace it when floated on water maintained at a given temperature. The water thus gains entrance to the float apparatus and causes it to sink. The penetration test is made by noting the distance that a No. 2 cambric needle penetrates into the sample of bitumen, vertically, without friction under a stated weight applied for a stated length of time, the sample being maintained at a given temperature. The ductility test is a measure of the distance a standard test specimen of the bitumen, having a minimum cross section of one square centimetre, will stretch without breaking when the specimen is pulled apart at the rate of five centimetres per minute. The so-called melting-point determination is made according to various methods, the object being to determine the temperature at which semi-solid or solid bitumens soften sufficiently to flow.

A determination of the flash point is useful in the examination of bituminous materials which contain any considerable amount of volatile products. The quantitative determinations of constituents volatile at certain temperatures to which the bitu-

mens may be raised during application is also of importance in order to ascertain what changes, if any, may be expected to take place in the material during application. Residues obtained from volatilization tests are therefore often examined for comparison with the material from which they are derived. Distillation tests are in a miniature way conducted according to the methods of fractional distillation employed in the manufacture of bituminous road materials, and a quantitative determination is made of the various distillates and the residues so obtained.

The determination of total bitumen is made by digesting a weighed sample of the material with carbon disulphide, which dissolves the bitumen. Any material not dissolved is then filtered off and weighed, the difference between the two weights giving the amount of total bitumen. The action of certain selective solvents, such as carbon tetrachloride, acetone, dimethyl sulphate, and petroleum naphthas, often gives valuable information concerning the characteristics of bituminous materials. These solvents do not necessarily dissolve all of the bitumen present, and a separation of certain constituents can therefore often be made by their use. Many other tests are also employed in the examination of bituminous road and paving materials which need not be mentioned in this paper, as it is impossible to describe them and discuss their application without entering into great detail.

In conclusion, it may be said that the examination of bituminous road and paving materials may be made for the purpose of identification, control during manufacture, ascertaining whether or not they conform to specifications, and for research investigations. When these materials are purchased under specifications, the necessity for systematic and careful sampling and the examination of every shipment cannot be overestimated, owing to considerable variations which are, at the present time, of common occurrence. The preparation of specifications for bituminous materials is a matter which should be handled by those familiar with their characteristics and value for different types of construction under different conditions, or else the specifications are apt to be not only worthless but so worded as to defeat the object of the party by whom they are prepared.

Writing on Blue Prints. ANON. (*Amer. Mach.*, xxxv, 18, 848.)—There are several methods of writing in white on blue prints. Commercial white ink can be used, or a solution of "Chinese white" in water, mixed to the desired consistency, or a bleach or a solution of soda. (Probably "chlorinated soda" is meant.) Ammonia water can be used, but is too thin to work well. Sometimes a few drops of bright red drawing ink are added to the solution, which makes pink marks and lines and shows plainly that changes or additions have been made to the print. To bleach a brown negative print, a solution of mercury bichromate or mercury bichloride works well. The strength to be used varies according to the intensity of the print.

Aluminum in Brass Alloys. ANON. (*Amer. Mach.*, xxxvi, 2, 64.)—Aluminum should not be used in brass or bronze alloys, for, although it is a deoxidizer, it has a bad effect, as aluminum oxide does not seem to free itself readily from the metal. Phosphor-tin or phosphor-copper is a better deoxidizer. The best way to keep metal clean is to prevent it becoming foul; that is, to melt all alloys under an ample cover of charcoal or to use a little flux in each pot. The flux or charcoal must be skimmed off before pouring the metal.

Decomposition of Nitric Acid by Light. W. C. REYNOLDS AND W. H. TAYLOR. (*Chem. Soc. Proc.*, xxvii, 306.)—On investigating the decomposition of nitric acid by light, it is found that the reaction is reversible; the products of decomposition slowly recombine more or less completely in the absence of light. It is proved that pure anhydrous nitric acid decomposes very slowly in the dark, giving the same products of decomposition. Mr. V. H. Veley says that the observation that the reaction, $4HNO_3 = 2H_2O + 2N_2O_4 + O_2$, is reversible on alteration of conditions is of special interest, and is in accordance with the results obtained in the study of other reactions in which nitric acid took part. The extent of the decomposition and recombination is illustrated by a series of curves.

A New Malleable Copper Alloy. ANON. (*Metal Ind.*, x, 1, 6.)—This new alloy is known as "Ogala" metal, and has many good properties in the line of malleability and ease of casting. At red heat it is highly malleable, is very hard and tough, but gives no difficulty in working. Its hardness and toughness increase up to a certain degree, the longer it is worked under the hammer or the rolls. At red heat it may be rolled to the thinnest sheets. It is of very low specific gravity. It melts between 950° and 1000° C. Its shrinkage in casting is only from 0.2 to 1 per cent. With care it can be cast. It is melted in graphite crucibles and poured quite hot. During the melt it should be well stirred, and covered with charcoal powder to prevent loss. It is made by Louis Ebbinghaus, in Hohenlimburg, Westphalia.

THE PRACTICAL APPLICATION OF SCIENTIFIC MANAGEMENT TO RAILWAY OPERATION.

BY

WILSON E. SYMONS,

Chicago, Ill.

(Closure by the Author.)

NOTHING but ingratitude could possibly prevent my first utterance being an acknowledgment of the very complimentary manner in which my paper has been received and discussed, and I wish to express my thanks to all concerned.

Those interested in the management of railway properties have, I trust, had an opportunity to get the benefit of the views on both theoretical and practical sides of the question, and it only remains for me to review the remarks of the different gentlemen who so kindly took active part in or otherwise contributed to the discussion of my paper.

MR. F. H. CLARK. To my mind, the two salient points in Mr. Clark's remarks cover the question very nicely and strongly endorse my position throughout.

It might be stated that the Baltimore and Ohio Railroad, of which Mr. Clark is an officer, has an earning capacity of about $90,000,000 a year. Under a very able and aggressive management, the road is being systematically rehabilitated to increase its efficiency as an operating unit. In Mr. Clark's own field of activity—that of Maintenance of Equipment—the expenditures last year amounted to more than $16,000,000, which sum was this year reduced by about $492,000.

MR. S. M. VAUCLAIN. I am not surprised that Mr. Vauclain cannot endorse in his remarks either the attitude of those who so severely criticise our railway managers or the methods of relief they propose, especially as I have already had occasion to make a study of the plan of organization and the degree of efficiency resulting therefrom in the plant with which this gentleman is connected.

With respect to the isolated location of many of the repair points on the Santa Fe, as compared with other lines, I would reply that my analysis of this same subject under the sub-heading

of "Unit Costs Itemized" (see Emerson) enables a comparison of cost supervision of Mechanical Department to be drawn between the Great Northern—practically a mountain road—and the Santa Fe. The Great Northern has a greater number of Mallet engines than any other railway in America, if not in the world. It has an average of one locomotive to every 6.46 miles, while the Santa Fe has one locomotive to every 5.12 miles. In other words, the Great Northern's equipment is more scattered than that of the Santa Fe by 24.6 per cent., while the cost for supervision of the Mechanical Department on the Great Northern is $23.10 per mile, as compared with $53.66 per mile on the Santa Fe, a figure 132.29 per cent. higher.

Mr. Vauclain also calls attention to the greatly increased size of locomotives on the Santa Fe road. It is true that this line, like many others, has purchased many new locomotives having two or three, and in some cases four or five, times the tractive power of some of their old light engines still retained in service. Actual figures indicate that the average tractive power of all engines in 1900 was a little over 16,000 pounds, while in 1910 it was 29,803 pounds. In connection with these figures it should, however, be borne in mind that the company still owns and operates over a thousand medium or light-weight locomotives, many of which were owned and operated in or prior to 1900, and that these engines suffer an actual reduction of effective tractive power due to their boiler pressures being gradually reduced on account of age. These locomotives, too, are now being used in lighter service, on branch runs, and on less important trains, etc., hence their cost of maintenance should really be less now than when they were in the heavier service. This fact, taken into consideration with the increased size of new locomotives on all other trunk line railways besides the Santa Fe, should bring the relative cost per engine mile on this road to about the same as that on other roads.

An examination of the table on page 381, giving the average diameter of cylinder in inches and the cost per inch of cylinder diameter in dollars on twelve railways running west from Chicago, will indicate that on this basis there is only one line showing a higher cost than the Santa Fe. This line, moreover, does not extend across the Mississippi Valley to the labor and material markets of St. Louis and Chicago, but is confined to an entirely

mountainous country where the maximum prices for labor and material obtain.

The point of speed, also included in Mr. Vauclain's criticism, applies to all transcontinental or trunk lines, and consequently affects the cost of maintenance of each to the same degree.

The comparative figures of costs, etc., presented in my paper were taken from the companies' annual reports, or their sworn statements to the Interstate Commerce Commission, and, except for any error that may have been introduced in calculating percentages or copying, are a correct representation of actual facts or conditions.

MR. E. L. CONRAD. The purpose of my rather extensive display of statistics was to endeavor to show that there was no substantial reduction made in repair costs of the Santa Fe system during the Emerson period, and Mr. Conrad, in his remarks, brief but well-chosen, has stated that this fact is true.

Coming from a gentleman who is personally familiar with every item of expense I have quoted, and who, on analyzing these items, would readily bring forth his criticism if warranted, his statement I consider to be a strong endorsement of my paper.

MR. WALTER V. TURNER. The fact that the Westinghouse Air Brake Company, like the Baldwin Locomotive Works, is operating on a highly efficient and most successful commercial basis, without any of the proposed Scientific Management schemes to which this paper is addressed, and that the prominent officers of these manufacturing plants frankly style the term a misnomer, or, as Mr. Turner puts it, a "premium on bad work," constitute a very strong endorsement of my estimate that the plan might be applied to something less than three per cent. of railway operation.

Mr. Turner, having been on the Santa Fe road when the system was inaugurated, undoubtedly had full opportunity to observe the personal workings of Mr. Emerson's Scientific Management plans, and I consider his opinion of more than ordinary importance in connection with this subject.

MR. G. R. HENDERSON. It appears to me that Mr. Henderson's criticism of "saving at the spigot and leaking at the bung" is not only a strong endorsement of my paper, but is tempered with much charity towards those who so openly accuse

railway managers of inefficiency and have made such a dismal failure in trying to support the unwarranted charge of their own proposed remedies.

MR. GEORGE J. BURNS. Mr. Burns's remarks being quite clear and consistent with the subject to which my paper was addressed, there is really not much for me to say in reply to them.

It is at once evident that Mr. Burns's long-extended and successful experience in shop management, handling men and machines, to obtain a fair average output from both, has greatly influenced his opinion of "scientific managers" and theorists who have never been able to solve the "human equation."

Mr. Burns clearly defines the popular understanding of the term "Scientific Management," and proves conclusively that this is erroneous, and that by commanding the best natural ability and by assimilating outside suggestions the railroads are, and have been all along, actually applying the real system.

MR. B. B. MILNER. In his discussion Mr. Milner has brought out some interesting and valuable points, and has submitted notes on "Increasing Operating Efficiency," which contain many useful suggestions.

I contend, however, in opposition to Mr. Milner's observations on the interpretation of the term "Scientific Management," that there can be no question as to the employment of the ablest men known in the solution of the problems under consideration, with the view of securing maximum efficiency in railroad operation; also, I hold that such talent is the embodiment of engineering principles on the broadest lines.

On page 10 of my paper I stated: "The estimated probable economies from this new plan in railroad operation will be confined to such branches as in my judgment are susceptible of being placed on a comparative basis with large manufacturers of standard articles." It should be clear from this as to what is the interpretation and scope of the plan.

Further, in the matter of the percentage of railway employees to whom the system (even in a modified form) would apply, I state most emphatically that about 12 per cent. of the 48,000 machinists and 5 per cent. of the 195,000 other shopmen, who are engaged on a regularly fixed class of work in the large general shops, could work under it. In other words, the fraction of

men affected by it would be .008, or eight-tenths of one per cent., of the whole. This is probably about the figure, but, to be more liberal, in my paper I calculated the percentage on practically double the number of shop and mechanical employees and added the 5,867 telegraph operators. Estimating the economies at 15 per cent., I therefore obtained the figure .0289.

Although I stand committed to the recognition and employment of the ablest talent in the railway or engineering field, the fact that I estimate that less than 3 per cent. of the carrier's employees can be put on a comparative basis with those employed in mills, shops, factories, and other manufacturing plants, must not be construed that I regard all of the remaining 97 per cent. as being up to the standard of efficiency or even a good maximum average.

The question under discussion is, however, so clearly defined on the title page of my paper and elsewhere throughout, and the kind of Scientific Management has been so clearly outlined in the publications mentioned, that there should be no doubt in the mind of anyone familiar with railway operation just how far this plan could be advantageously applied, and, in order to comply with the text, this must, of necessity, be aside from economies through other channels.

I have estimated that the term applies to less than 3 per cent., and I regard it as more than probable that this figure could be reduced. If others estimated 16, 25, 50, 75 per cent., or even "Our" railways, which means 100 per cent., should be managed by this scheme, as the prosecution, principal witness, and almost the entire press claimed, in the case referred to, could and should be done, it remains for such claims to be substantiated.

PROF. WILLIAM J. CUNNINGHAM. I have already read Professor Cunningham's article in the *Quarterly Journal of Economics*, and I consider it as containing much that is of value to the practical railroad man and to anyone interested in railroad problems. To me the article is an exposition of the fallacious claims of savings made on the Santa Fe system.

In reply to Professor Cunningham's remarks, I might say that there are many items of expense on a railway that, though seemingly extravagant, may represent an integral part of the cost of a certain operation in itself highly efficient. The theory of

Scientific Management as presented by its advocates would result in a levelling or evening process by establishing unit costs which would obtain throughout. From the point of view of a railroad man, the theory would therefore be entirely inapplicable to such items, although apparently not so to one outside.

The attitude of railway managers and their efficiency engineers or experts is not, as is generally supposed, one of hostility toward anything that will result in more economical operation. In fact, these men are not only open to receive and embrace such plans or methods, but are actually seeking them. At the same time, however, they are very properly guarding the property in their charge from the adverse effects of experimental schemes that would tend to either injure or destroy their organization and affect their earnings. Many of the plans for saving great sums to the railway companies that are perfectly feasible from a theoretical stand-point are known to be impracticable by the men in charge of railways, and these men, therefore, very properly decline to allow their organizations—and consequently their service to the public—or the company's earnings to be interfered with or jeopardized, and the penalty of their foresight and loyalty to their employing companies is not infrequently the bitterest criticism.

I feel sure that Professor Cunningham and others who possess a broad and liberal knowledge of railway affairs in general will agree that the men who have devoted their lives to the various phases or branches of railway operation are the men best able to judge as to what methods should be employed in effecting economies.

Two or three conclusions drawn by Professor Cunningham in his paper already mentioned I would refer to as having a special bearing on the subject under consideration in my paper.

Speaking of Mr. Emerson's claims of the millions saved on the Santa Fe by the adoption of his "Scientific Management" plan, Professor Cunningham says:

> "In the first place, the new system was introduced in the Santa Fe shops just after the collapse of a lengthy strike of machinists. Shop forces were demoralized and maintenance costs abnormally high, because of the inevitable employment of incompetent men to take the place of the strikers. A return to normal conditions under any system would have shown a marked improvement when results were compared with the former abnormal period."

Further:

> "Mr. Emerson's usual method of expressing the expense of locomotive maintenance is in cost per 'Road Unit.' This is an unusual and misleading average, because it includes the weight of the locomotive as a factor and assumes that the repair cost varies directly with the weight—which assumption is not entirely correct. In this case, Mr. Emerson's 'Road Unit' gave a favorable showing to the new system because of the purchase of a large number of new and heavy engines."

Thirdly:

> "Since the Santa Fe experiment lacks convincing proof, the railroad managers are forced to turn to industrial or manufacturing concerns to learn of the merits of 'Scientific Management.'"

Professor Cunningham's conclusions may therefore be analyzed as follows:—

Mr. Emerson did not reduce the cost of repairs to locomotives from $4,165 to $3,016 per year, as claimed—this reduction being simply due to a return to normal conditions, following an expensive strike.

Mr. Emerson's "Road Unit," on which he bases his economies, is unusual and misleading.

Finally, Professor Cunningham says that the efficiency or Scientific Management experts must "lay less stress on system, dependent sequences, etc., and acquire more knowledge of practical railroad problems," with all of which I concur, since it constitutes a strong endorsement of my position throughout.

DR. ANGUS SINCLAIR. Dr. Sinclair's reference to the general attitude of workmen in American railway shops and the probable effect on them of the so-called Scientific Management plan brings prominently into view a question that has been given little, if any, attention by the majority of persons who have written and said much about this system.

This feature, however, which I term the "human equation," is specially referred to in the conclusions on page 43 of my paper. It becomes of great importance when the fact is borne in mind that, even under present conditions, it is almost impossible to secure a sufficient number of men of the various classes to handle railway work. Owing to fluctuations in traffic, it not infrequently occurs that the maintenance of equipment or movement of trains

is considerably interfered with on account of inability to sufficiently increase the working forces to take care of the increased volume of business.

There are two reasons for this—an insufficient number of applicants and the actual number rejected owing to the rigid physical requirements with respect to age and general physical condition. It is a fact that a large percentage of the various classes of labor common to all industries can and do find employment in other lines when they are unable to secure work with railway companies, owing to too strict physical requirements.

Under the proposed plan of Scientific Management, the "speeding-up" process would unquestionably be one of the cornerstones on which the system or plan would stand, should it ever exist. Therefore, another culling-out process would follow that of the physical examination, so that ultimately a full realization of the economies claimed for this plan would be predicated upon the use of 100 per cent. efficient men, or, in other words, perfection—and it is, on the face of it, impossible to organize and maintain such a standard. Moreover, such a scheme is contrary to public policy and at variance with the Constitution of the Commonwealth.

Some years ago a judge presiding over a court in Tennessee, at a case wherein the question of a certain railway company's liability was at issue, ruled, and so instructed the jury, that the company was liable, for the simple reason that it did not have the highest grade of employees to protect property in its charge, and a verdict was consequently rendered against the defendant company. The case was, of course, appealed, and when it reached a tribunal that was uninfluenced by local prejudice the former verdict was not only set aside and the company held not liable, but the trial judge was severely criticised for embodying in his charge to the jury instructions that were contrary to public policy. The principal point established by the Supreme Court was that it was impossible for any company, particularly a railway company, to have all first-class employees. It would be contrary to the policy of the railroads to expect to obtain all the best men our country produced, thus casting all the inferior men into other lines of industry.

There can be no arbitrary time limits predetermined and established for the thousands and thousands of operations in railway

work without a long series of time-studies with stop-watches and other means of espionage over workmen which, when finally completed and put into effect, would result in crowding out of service thousands who are now valuable and efficient employees and useful citizens, but who would probably be declared inefficient by this proposed technical or scientific "yard-stick."

Dr. Sinclair has very clearly pointed out that this sort of thing would confuse workmen without reflecting any glory on the management, and I feel prompted to agree with him that it would result in all the adverse conditions he mentions, together with many others that he has doubtless in mind.

MR. J. SHIRLEY EATON. I regard Mr. Eaton's criticism as of a character or tone that invites co-operation in the matter of the problems under consideration. There are doubtless many problems pertaining to the physical operation of a railway and to its statistics that do not appear to any one of us in the same light as they would to another. Difference of opinion largely reflects our angle of vision, and is also an index to our difference of environment.

With reference to experimental features of the earlier railroads, I am inclined to the belief that there was far less experimenting then than now in this field, and that many of the improved conditions accorded to the result of experiment were, and are, the outcome of the well-matured plans of highly efficient men in their chosen profession.

To quote examples, a railway is built with light materials—light steel, ties, bridges, etc.—is provided with narrow fills and cuts, and is operated with light power and equipped with light cars, and other facilities in proportion.

After the line is opened and earnings either provide funds or establish sufficient credit for the company to refinance the property, it is usually rehabilitated with heavier steel, larger and more ties, rock ballast, heavier bridges, etc., and those who so freely criticise the railways immediately say that the first efforts were an experiment and were a waste of time and money. Actually, however, far better use of the original funds and facilities at hand had perhaps been made than is done by those who rebuild a line—and not infrequently receive credit for correcting the alleged folly of an experiment. Following the rehabilitation of

the permanent way, engines and cars are replaced by heavier types—side tracks must be lengthened, new turn-tables secured, and the round-houses and shops enlarged—all of which is not infrequently termed "experiment." The same is true with regard to the handling of the men employed. Railway officers have not experimented with men, but have simply moved with the times in their endeavor to develop efficiency of a high order.

A notable practical example of the above was the rehabilitating of the Union Pacific Railroad some years ago. Some referred to this great engineering and commercial feat as casting a reflection on those who located and built the original line. The chief officers engaged in the reconstruction and shortening of the road, however, frankly admitted that it was extremely doubtful whether any other living man could have done so well under the circumstances as did Gen. Grenville M. Dodge in the original location and construction of it.

Many other similar cases might be cited. I myself have designed, purchased, and maintained locomotives of a size and capacity much below what I considered the most economical from an operating stand-point, but they were as heavy as the bridges and other superstructures would support. As, however, funds were not forthcoming to rehabilitate the roadway, etc., in spite of the necessity of supplying greatly increased power to move the volume of business offered, it was incumbent to do the best that could be done under the circumstances. Later on, new bridges permitted using heavier engines, and perhaps the displaced engines were referred to by some as "experiments," although they worked to maximum efficiency in their "day and generation."

Mr. Eaton is correct with regard to the railway business having in many respects taken on a form of strife. There are several very prominent factors exerting a constant influence in the direction, as indicated by Mr. Eaton, of the strenuousness of railway life, so that this strife may be found in most all branches of the various departments. It represents the components of all the influences tending in the direction of all the executives charged with the management of the properties. The owners are solicitous as to their investments, which prompts the management to exert their energies to the end of securing the greatest possible returns from operation; this in turn means that, through the medium of the traffic officers, they are at all times striving to

secure the greatest possible volume of business over their rails; through the legal department they are striving to secure the most advantageous position in all matters affected by the courts; the cost of transportation is sought to be lowered by the operating department.

In opposition to these factors, almost every employee of the line is constantly seeking—and many demand through their organized bodies—increased compensation. The labor organizations are not asleep, and have long ago learned the most effective manner in which to secure favorable consideration—and in the application thereof it is not infrequently the case that prominent trunk lines are, in the matter of wage questions, placed in competition with one another. As a result and as the bidding—as it may be termed—progresses, the companies are placed, by means of concessions and compromises, in the position of practically competing with one another in the purchase of labor at the lowest possible figure. There is, in the end, a gradual increase accruing to the labor organizations in consequence of this competitive, collective bargaining. As Mr. Eaton states, this has assumed a condition bordering so closely on physical strife that doubtless some of the best men in the railway field have been sacrificed.

Other contributing causes for this physical strife are such as the railway companies themselves have not occasioned by their own methods. An ever-discriminating and sometimes unreasonable public is largely responsible more than any other one factor. About forty-seven different legislatures have for years been making laws mostly hostile to railway interests, many of which have been unconstitutional. These, together with the conflicting rules of state and national railway commissions, sometimes render it totally impossible to observe the rulings of one State without violating those of another, so that it is small wonder that the railway officers are constantly held under a high nerve tension from this cause alone.

Finally, after years of strenuous combating of these combined conditions, there becomes famous in a night the "Scientific Management" craze. This, by disseminating such statements that $365,000,000, and even $730,000,000, a year can be saved by the railways, has had the effect of further embittering the people against railway interests, and has rendered it much more

difficult to operate railway properties with that degree of economy which, in the absence of these adverse influences, would be easily attainable.

Mr. Eaton says that preconceptions and vague impressions have played so large a part in the questions under consideration, in spite of the fact that the figures given in my paper were actually quoted by Scientific Management exponents in support of their statements and claims. One advocate actually pointed out that a prominent industrial concern coerced the railways into purchasing its products at a probable loss or waste of $2,000,000 a year, and offered Scientific Management as a remedy for the losses.

Another advocate offers the following unit costs for maintenance of locomotives and cars.

Locomotives, per mile run	$0.06
Freight cars, per car per year	$35.00

On this basis the total cost in 1909 should have figured out as follows:

Locomotive miles, 1,529,454,537 at 6 cents per mile	$91,771,312.22
The actual cost of Maintenance and Depreciation was	134,675,802.00
Which is in excess by	32,904,490.00
Freight cars, 2,250,000 at $35 per car per year	78,750,000.00
The actual cost in 1909 was	160,758,186.00
Which is in excess by	82,008,186.00

Or over one hundred per cent.

So that on these two items alone $114,912,676 is alleged to have been wasted.

It would appear, therefore, that Scientific Management advocates are actually guilty of the very offense of which they are by Mr. Eaton charitably absolved.

As to the introduction of the efficiency engineer, there is really not a wide range of difference between railway managers and railway efficiency or consulting engineers. The fact must not be overlooked that discouraging influences and impediments to progress are being overcome by the various able and efficient railway managers all along. American railways are producing transportation for less than any other country in the world. They are paying higher compensation and operating with a less force, as is illustrated in the following table of ratio of number of men per mile of line:

United States	6.38
United Kingdom	27.
Germany	22.
France	16.
Switzerland	15.
Russia	21.
Belgium	25.
Austria	18.
Italy	16.

An army of railway efficiency engineers is constantly employed and is achieving results in its work, so that any criticism of these would, under the circumstances, appear unwarranted.

MR. FRANK B. GILBRETH. I find myself unable to agree with Mr. Gilbreth in any of his conclusions with respect to the practical application of Scientific Management to railway operation, although I realize that his opinions are entitled to respectful consideration.

Mr. Gilbreth is quite sure that the railways will be much more efficient when they adopt the Taylor System of Scientific Management; he is also equally sure that they will adopt it.

The plan of so-called Scientific Management under consideration in my paper was very clearly defined in the testimony before the Interstate Commerce Commission on the rate cases. It was also given much publicity about the same time through the press. In a general way it is the so-called Taylor System, and my opinion is that there is not the remotest possibility of the railway officers adopting this system or of the employees working under it. On the other hand, too, there is not the remotest possibility of any diminution in the concentrated efforts of our railway managers and their departmental heads, many of which latter are high-grade efficiency engineers, to maintain economy. They will proceed in the future, as they have done in the past, in the solution of all problems pertaining to economical operation, to the end that the majority of our railways in America shall remain in the lead of all other corporations or concerns where high-grade efficiency engineering is concerned. Most of the alleged wastes or inefficiencies pointed out by those lacking in knowledge gained from practical experience in railroad work are largely, if not wholly, such economic wastes or essential costs as are absolutely necessary in the operation of a high-grade transportation plant, which will never be prevented.

In stating that the so-called Scientific Management plan under consideration will not be adopted and used by the railways, I do not wish to convey the idea that the plan reveals anything but the results of continued and hard study of the subject of scientific shop management on the part of its originator. I regard it, on the contrary, as having brought much distinction in its field of usefulness, but add that its methods are in this case not applicable.

No doubt many who have read of Dr. Taylor's great achievements in the engineering world have been led to believe that the same economies could be effected in all items of expense in railway operation. That this is not the case, however, can be best shown by taking a particular example.

Some ten or fifteen years ago the efficiency engineers on our railways began to stir up the machine-tool makers, first with a request, then a demand, for machines and tools that would stand up under heavier loads and increased speeds, thus effecting an increased output. Although some few of these were a little slow in getting into action, the progressive motive-power officers of the American railways continued to press until the demands were met, and as a result the designing engineers and manufacturers have, jointly with the railway efficiency engineers who use their products, brought about great economies in machine shop output.

Although the above is the case, the fact should not be overlooked that the proportion of the operating expenses of a railway that would be controlled or influenced by the benefits derived therefrom is decidedly small. For example, the development of high-speed tool steel for turning steel tires had very little effect on operating expenses, as is evidenced by the following figures, taken from the statistics of one of our leading trunk lines:

Total number of employees	39,000
Total operating expenses, over	$37,000,000.00
Maintenance of equipment	9,500,000.00
Monthly pay-rolls, Mechanical Department, over	400,000.00
Monthly expense of turning steel tires	500.00
Ratio of steel tire expense to shop rolls	.0012
Ratio of steel tire expense to maintenance of equipment	.00006
Ratio of steel tire expense to operating expense	Not given

It should, therefore, be clear to anyone that even the maximum improvements or economies effected by the introduction of improved tool steels would only touch an infinitesimal part of the shop work, and entire maintenance of equipment, which is in turn only an item, amounting to about one-fifth, or 20 per cent., of the total cost of railway operation.

Passing from shop operations to office expenses, Mr. Gilbreth says: "We have applied the Taylor plan of Scientific Management with a large increase of efficiency to office employees, as well as to those who do manual labor." I can only say in reply to this that for the one line that has been cited as an example of the wonderful economies effected claims have been made which have on analysis proven to be without support.

Mr. Gilbreth's conclusions on the application of the plan to locomotive repairs must be formed from a theoretical view of the matter, for I venture to say that if placed in charge of maintenance and repairs of locomotives in a large round-house for even a short period it would be impossible for one to form such conclusions.

Lastly, I would say that the problems of "Practical Application of Scientific Management to Railway Operation" and of "Practical Application of Scientific Management to Manufacturing Plants" have very few, if any, points in common, and, no matter how thorough an investigation were made of the latter, the experience gained would still be entirely inapplicable in proposing any method of or attempting any solution of the former.

MR. CHARLES BUXTON GOING. Mr. Going comments on increased size of engines, and states that comparison on any other basis than the tractive unit would be worthless. In reply I would say that it is a matter of common knowledge that all trunk lines have materially increased the size of their power in the last twenty years, and particularly in the last decade. The Santa Fe has made remarkable strides in this direction, but as it has done so not independently, but in common with the other lines, the relative difference in cost per unit of all lines should be about the same.

An examination of the Santa Fe annual report for 1911 discloses the following figures with reference to locomotives:

Number of engines	1,997
Number of engines with less than 100 tons on drivers	1,770
Number of engines with more than 100 tons on drivers	227
Per cent. of locomotives with more than 100 tons on drivers	11.3
Number Mallet engines	58
Per cent. Mallet engines	2.9

(While there are about 58 Mallet engines shown in the 1911 report, many of them were received toward the close of the fiscal year. During the period covered by the maintenance items for this year there were approximately 35 Mallet engines, or about 1.8 per cent.)

Of the 90 per cent. of engines weighing less than 100 tons on drivers, 1,601, or 80 per cent., of these have less than 75 tons on drivers. Further, it may be stated that included in this schedule of power are many old light engines that actually decrease in size by age, and, as these are mostly assigned to lighter service, they should be much less expensive to maintain than they were prior to the purchase of the modern heavier power.

The light power is divided into the following classes:

Switch engines	144
Eight-wheel	242
Mogul	57
Ten-wheel	433
Twelve-wheel (only 52.17 tons)	6
Consolidation	339
Total	1,221
Per cent. of total equipment	61.0

From the foregoing it is quite clear that, while the Santa Fe has added many new engines to its equipment, it, like other lines, still owns and operates a majority of much lighter engines.

The average tractive power of locomotives on the Santa Fe for the past six years was as follows:

1906	27,684 pounds
1907	29,229 pounds
1908	29,757 pounds
1909	29,714 pounds
1910	29,803 pounds
1911 (58 Mallet engines)	30,824 pounds
Increase in tractive power (1906–11)	11.3%

Cost per engine per year for maintenance,	
1906	$3,101.00
1911	4,544.00
Increased cost over 1906	46.5%

Again, a comparison may be drawn between the sizes of engines on some of the lines in question on the basis of average diameters of cylinders. The following is a tabulated display of this factor in inches, together with average cost of maintenance per engine per year and cost per inch of cylinder diameter per year, on twelve different lines:

		Average diameter of cylinders in inches 1910.	Average cost per engine per year to maintain in dollars.	Cost per inch of cylinder diameter in dollars.
1	Northern Pacific	20.70	$2,481.00	$120.00
2	Great Northern	20.67	2,841.00	137.39
3	Southern Pacific	19.93	4,218.00	211.64
4	St. L. & S. F.	20.00	2,923.00	146.15
5	C., R. I. & P.	20.00	2,478.00	123.90
6	C., B. & Q.	19.90	3,087.00	155.12
7	Union Pacific	20.45	3,687.00	180.29
8	Missouri Pacific	19.60	3,393.00	173.11
9	M., K. & T.	19.30	2,783.00	144.19
10	C. & N. W.	19.08	2,527.00	132.44
11	C., M. & St. P.	18.77	2,523.00	134.41
12	A., T. & S. F. Ry.	18.54	3,832.00	207.22
	Average	19.74	$3,148.00	$155.44

These figures are self-explanatory and confirm my contention that analyses of unit costs based on size or capacity can quite properly be made.

With reference to the comparison of cost per engine per year for maintenance on different lines of railway and on the same line of railway for different years, to which comparison Mr. Going takes exception, adding that "comparison on any other basis but the tractive unit would be worthless," the presumption is not made by the writer that, in the preparation of operating statistics of railways, the method employed to show the general average earnings per train mile, the average cost for maintenance of way per mile, the average cost per locomotive per year, per freight and passenger car per year, etc., gives in any case the exact cost of each unit involved. For example, on a system where the average earnings per mile per year are $10,000, it is not unlikely

that some miles are being operated at a loss. The same may be said to be true of locomotive maintenance. A line showing an average cost of $3,000 per locomotive may have spent as high as $10,000 on some certain locomotives, while on others possibly only about $500 or $600. The ready comparison of the costs on their own line and on other lines, for the various periods made by the method of averaging, is, however, the one generally accepted by the managers of American railways.

A search of the annual reports of railways of the United States reveals the fact that Mr. Going's "unit costs based on tractive power" is conspicuous by its absence. The Railway Presidents' annual reports show these figures in average cost per locomotive per year, average cost per locomotive per car mile, average cost per car, average income or expenditure per car mile, etc.

Just what my position is in respect to Scientific Management is brought out by the qualifying clauses on pages 10 and 18 of my paper, and I have therein confined myself to the task indicated —that of establishing an approximate line of definition of the practical application of scientific management to railway operation.

I repeat here that there is no comparison between the daily duties of section laborers, section foremen, engineers and firemen, brakemen, conductors, etc., on the one hand, and of machine operators on the other. The daily duties of the former cannot be predetermined by some planning department in an office.

With respect to the switch-tenders, it is quite proper to show that the number of these has been reduced to a minimum and that their rate of pay will not permit of any reduction, so that no portion of the proposed $365,000,000 to be saved per year could be derived from this source.

The next item is that of employees on floating equipment. Their average compensation is now $2.31 a day—which includes captains, first, second and third officers, chief engineers, assistant engineers, stewards, pursers, petty officers, and the remainder of the crews. No reduction could be made in this rate, which is already below the average for the character of work performed. Neither could the number of these men be reduced, as their duties are usually clearly defined, as I already stated, by United States laws governing steamboat service.

As to the mixed classes, which include inexperienced men in railway service, what I have said of the track-, engine- and trainmen, as compared to machine operators, also applies to these.

Mr. Going states, with regard to economy effected by first-class supervision: "Whether the average man is firing a locomotive or tamping a tie, he can certainly learn to do it better under the guidance of a better-than-average man." I think I have already expressed my willingness to admit that first-class supervision would effect economy to the railway company.

Consider in tabulated form figures concerning some of the principal men connected with locomotive operation and fuel economy.

Engineers	57,077
Firemen	60,349
Mechanical officers	2,000
Travelling engineers	900
Members International Railway Fuel Association	147
Members Air-Brakemen's Association	200
	120,673

As all of the above are not fuel experts, and as many of them devote much of their time to other matters than fuel problems, it is quite proper to subject this list to a process of elimination.

Of the 57,077 engineers, there are no doubt many that practise the most rigid economy in the operating of engines in their charge and guard their employers' property as carefully as if it were their own. Such number among them the ablest fuel experts known, and it is from their ranks that men are selected for the advanced positions of travelling engineer or road foreman of engines. There are no statistics to show the average percentage of the number of engineers that would come within this class, but many years' experience in the examination, employment, handling, promoting, and otherwise dealing with both engineers and firemen, studying their records, performance sheets, etc., enables one to make a reasonably fair estimate of fifty per cent., and of the remainder I would venture to say that at least half are not wasteful.

Taking the estimate of 50 per cent., however, we have on the

scene of action at all times 28,538 high-grade fuel experts who are as economical as transportation conditions will allow.

Now, considering the firemen, it is well known that the best engineers do not tolerate inefficient firemen, and so it may be said there is an equal number to that of the engineers endeavoring to save every pound of coal possible.

We now have 57,077 men constantly in service with this latter object in view.

There are over two thousand mechanical officers, and more than one-half of these—to form a conservative estimate—contribute much to fuel economy.

Travelling engineers and road foremen of engines are drawn from the very best engineers on the road. They are experts in locomotive operation, and are constantly on the "firing line." Approximately 900 of these must be added to the above.

As regards the members of the International Fuel Association, 150 in number, these are interested in fuel economy, but, since many of them are confined to office work, it would be fair to consider 100 of them as contributing to practical saving of fuel.

To the already considerable number might very well be added a large percentage of the air-brake instructors, many of whom teach fuel economy in conjunction. Hostlers, trainmasters, and superintendents could also be included.

The completed list of fuel economists, therefore, stands as follows:

Engineers	28,538
Firemen	28,538
Mechanical officers	1,000
Travelling engineers	900
International Railway Fuel Association	100
	59,076

or about 59,000 of the best men available teaching and practising fuel saving.

That there is room for considerable further economy in this direction than is at present effected is not denied. Recent preventable wastes have, however, been grossly exaggerated by Scientific Management exponents.

The assignment of additional men of known ability in locomotive operation would secure the best possible service from

each employee to prevent all necessary waste of fuel. Beyond this no one can go. Scientific Management could not approach the case, and the Bonus System would have a demoraiizing effect.

Locomotive engineers and firemen are paid on a mileage basis, clearly defined in their schedule drawn up by their respective brotherhoods. The hours of departure, weight and speed of trains, number and duration of stops, etc., are all governed by the Transportation Department to suit constantly-changing conditions of service.

The quality of fuel used is influenced largely by two factors: its degree of purity and the manner of handling it from mine to engine. All coal is not first quality, and the railway managers will continue, in the future as in the past, to purchase that grade which, from the stand-point of sound business policy, is most suitable for their use.

One of the most important factors affecting the quantity of fuel used is the state of the weather, and, up to this date, I have not heard of any proposition to regulate this by Scientific Management! There are other factors just as variable as this, and the foregoing serves to show that these cannot be foreseen or provided for in any bonus system.

I stand committed to the highest possible efficiency obtainable by the employment of the best talent known in respective lines of work, and regret that I am unable to offer a better definition of my views on Scientific Management than was given in my paper.

MR. HARRINGTON EMERSON. At the risk of tiring some readers with what appears to me too voluminous a review, I will enter, as part of the record, extracts from the testimony and writings of different advocates of Scientific Management to which I have addressed myself (see Docket 3400).

Extracts from the testimony before the Interstate Commerce Commission in the rate case:

Page 14: "The Science of Management is new. Some of its principles were discovered and applied a quarter of a century ago by Fred. W. Taylor in the Midvale Steel Works. Other principles have been discovered and developed by him and by many others since. It was not until the publication of his essay on 'Shop Management,' in 1903, that the results of his work and

that of his associates, particularly H. L. Gault and C. G. Barth, were presented to the public in a comprehensive form; and it is scarcely more than three or four years since these principles developed into a science. (Emerson on Efficiency, and Going, Sante Fe Management.)"

Page 15: "Scientific Management is not merely competent and progressive management. 'Scientific Management' differs radically from the most competent and progressive management under the old system. It differs also from systematized management. The difference is one in kind. 'Scientific Management' differs from that now generally practised by the railroads, much as production by machinery differs from production by hand; and the 'Revolution in Railroading' and other industries, which must result from the introduction of 'Scientific Management,' is comparable only to that involved in the transition from hand to machine production."

Pages 18 and 19 (WHAT SCIENTIFIC MANAGEMENT INVOLVES): "In Scientific Management, therefore, results are predetermined. *Before* the work is commenced, it is determined not only as to what shall be done, but how it shall be done, when it shall be done, and what it shall cost."

Page 52 (PIECE WORK): "It must not be supposed that the introduction of the piece-rate system is 'Scientific Management,' or even an approach to it. On the contrary, the existence of the piece-rate system often proves the greatest obstacle to the introduction of Scientific Management."

Page 63 (ECONOMY NOT CONSIDERED): "Mr. Emerson: We never paid any attention to attaining economy. The only thing we paid attention to was the attaining of efficiency, feeling absolutely certain that economy would result as a by-product."

Pages 64 and 65 (SCIENTIFIC MANAGEMENT AND LABOR UNIONS): "The claim has been made, that 'Scientific Management and labor unions are inconsistent; that the organization of labor presents insuperable obstacles to the introduction of Scientific Management in railroads and other industries where unionism is potent. This claim we believe is wholly unfounded in fact.

(*a*) "Collective bargaining is alike an important function under Scientific Management as under the old system.

(*b*) "Unionism does not prevent the introduction of Scientific Management. It is true that unions have in some trades bitterly opposed the piece-rate or bonus system 'without Scientific Management,' just as they have opposed the day-rate system without Scientific Management."

Page 80: "Emerson.—Standards of maintenance-of-way vary. Innumerable assays of actual work show a maintenance-of-way labor efficiency of scarcely more than thirty (30) per cent."

Page 82: "Emerson.—The cost of fuel is, on all railroads, a large per cent. of the total transportation expense. It has been demonstrated that, by proper instruction, fuel consumption could be reduced at least one-half."

Page 84 (DEMANDS OF SCIENTIFIC MANAGEMENT): "The attainment by each railroad, for each operation, of the lowest cost attained by any other railroad for that operation, would not, however, satisfy the demands of Scientific Management. To attain only the best that has been done presents the beginning rather than the end of economies which Scientific Management contemplates. With the ascertainment of the lowest existing costs, the study must be made whether there are still waste time and effort involved in the best existing method of performing that particular operation, and of eliminating such waste when determined. And when that shall have been done, there will still remain the wide field of research for a better way of doing the same thing."

Page 88 (RAILROADS ARE NOT SCIENTIFICALLY MANAGED): "It is no doubt true that some of the railroads are competently managed, so far as that can be done under the old methods. Other railroads, while not managed competently as a whole, are no doubt competently managed as to particular departments, divisions, or operations. But, so far as appears in evidence, Scientific Management has not been introduced into any department of any railroad operating within official classification territory."

Page 92 (TRAFFIC ONLY EFFICIENT DEPARTMENT): "Mr. Emerson.—Large economies can be effected in all departments of railroad operation except traffic. The efficiency of the traffic by my standards is very high; that is, the efficiency of expense in the traffic departments."

Page 76: "Emerson.—No railroad has ever determined any cost standards, either for maintenance or operation of equipment, maintenance-of-way, or consumption of fuel; yet there is no railroad in the country on which each of these cost standards could not be determined in a very short time and with very close accuracy, at a cost equal to the saving effected in a single month."

Page 77: "Emerson.—Standardized locomotive repairs run from 3 cents to 6 cents a mile for maintenance. The actual average cost is 6 cents to 12 cents, therefore twice what they should be. The standard cost of maintaining freight cars is as low as $30 per annum. Actual average costs run from $45 on some roads to over $100 on others."

Page 179 (CONCLUSION): "This investigation has developed clearly that the railroads, to meet any existing needs, should look, not without, but within. If their net income is insufficient, the proper remedy is not higher rates, resulting in higher costs and lessened business, but 'Scientific Management,' resulting in lower costs, in higher wages, and increased business. If their credit is impaired, the proper remedy is not to apply the delusive stimulant of higher rates, but to strengthen their organization by introducing advanced methods and eliminating questionable practices. Thus they will maintain credit by deserving it."

Replying to Mr. Emerson's criticism of my paper in the order of its presentation, the first item is that of oil or lubrication. It should be noted that in this one connection Mr. Emerson agrees with me in three points:

1. That the Galena-Signal Oil Company's methods are those of efficiency engineering.

2. That the company deserves to be ranked among those engaged in effecting economy in railway operation.

3. That the company's methods have probably saved the railroads $10,000,000 in the past twenty years, and are now saving them about $10,000 per year on the item of lubrication.

Mr. Emerson thus takes part in stamping as unreliable the statements of the author of the article in *Hampton's Magazine*, wherein the oil company was accused of coercing the railways to buy from them at unreasonable prices.

I myself have had experience of the qualifications of the men employed by the Galena-Signal Oil Company. When I was

master mechanic on a mountain division of over 800 miles of a transcontinental line using a low-grade of oil with a high cost (almost $3 per 1,000 miles on locomotives) the oil was changed to Galena-Signal at *twice* the price per gallon. The cost per unit of service on the system was in many cases doubled, and I found it necessary to act quickly to prevent a cost of lubrication in my district that would invite unfavorable comment from my superiors.

My efforts brought greater returns than expected. The locomotive cost of almost $3 per thousand miles with cheap oil was reduced below $1.50 per thousand miles with oil that cost *double;* at the same time, the prairie or level divisions of the system, that should have made the best showing, remained slightly above their former cost with cheap oil. My own surprise was mild to that of others, particularly of my superior officer, the stores department, and the oil company, the impression being that I had in some manner gotten oil not charged to my district.

Again, when in the employ of the oil company itself, some years ago, in the capacity of mechanical expert, I found the conditions were extremely difficult on one of the home systems to which I was assigned. Constant practice of patience, tact, perseverance, and general knowledge of all matters pertaining to the question of lubrication and railway operation was necessary to meet them. The policy of the oil company was strictly observed without friction with department heads, in spite of frequent calls from the management and a saving of several thousand dollars per year, and better service was effected. I was later invited by the management of this same property to take charge of its mechanical department, including motive power machinery and rolling stock, and in this capacity received reports from the oil company's mechanical experts.

On two other railways, of which I was superintendent of motive power and machinery, there were similar relations between myself and the oil company's representatives.

During several years of special or consulting work, making examinations of and reports on railway properties, I have had opportunity to observe the prevailing practice on many other lines than the above, and it has often been my duty to analyze thoroughly this item of expense.

As the result, I am quite positive that the efficiency engineering methods followed by the oil company's high officials or their experts in the field bear little or no resemblance to the scheme of Scientific Management given publicity through the rate case testimony and other channels at that time, and to which I have addressed myself.

Mr. Emerson misrepresents my position when he commits me to the statement that I favored the application of available knowledge and skill in railroad operation to the items of lubrication and air brakes, but to no other. A glance at my paper will reveal to anyone the fact that I have placed no such limitations on the application as Mr. Emerson would have it believed.

I have endeavored to make it clear that I recognize the full value of engineering principles as essential to the success of any undertaking which involves the application of nature's forces to the service of man. I could not do otherwise at this stage of my work in the practical application of these principles.

My reference to certain industrial concerns is anticipated in my opening remarks. These companies are entitled to recognition for the progress they have made on the lines of efficiency engineering, and I offered the reference to them as a rebuke to the author of one of the articles who held the railways up before the public eye as examples of inefficiency, extravagance, and dishonesty, etc., and offered, as a cure, Scientific Management.

This same author having also pointed out the influence of a certain industrial concern on the purchase of oils, causing alleged waste, it appeared quite proper to go into details in this matter and show as a contrast the actual probable amount of savings effected.

I did not state in my paper, and have never stated, that Scientific Management on the Santa Fe Railway was a failure. I did say, however, and feel safe in repeating, that the figures given before the Interstate Commerce Commission and published to the world, with reference to the alleged economies effected on this road, would not bear analysis.

I stated, and repeat, that the high cost of locomotive repairs in 1904 and 1905 was due to the machinists' strike. (Mr. Emerson says that the strikers were "violently and destructively hostile.") Also, the reduction in cost in 1906–7 was that which follows the termination of a strike of this magnitude, and that

Mr. Emerson's employment on the line was merely an incident in connection with the road's operation. In fact, if neither he nor his men or methods had been employed at this particular time, the reduction in cost per locomotive should have been as much as shown.

In speaking of the great economies to be effected by the Scientific Management of Railways, and pointing to an example of what had actually been accomplished on one line using these methods, Mr. Emerson mentions the reductions in cost of belting, tool maintenance, and locomotive repairs.

I have just pointed out that the high cost of locomotive repairs in 1905 was due to the shopmen's strike, and the reduction in 1906–7 to the termination of that strike. Who knows but the item of belting costs may have been effected in a similar manner?

Belting is one of the many items of cost in connection with shop tools and machinery, and, as Mr. Emerson has clearly solicited credit for certain results under qualified conditions, it would seem quite proper to embrace all items of expense in the connection involved to make a correct analysis.

In speaking of the "untiring and intelligent support" rendered by Mr. Kendrick, Mr. Emerson fails to include many facts to which quite considerable importance is attached by others.

Belting is one of the items in the cost of shop machinery and tools that Mr. Emerson tells us was reduced from $12,000 to $3,600 per year. He fails to state, however, that during the four years—1901–4 inclusive—prior to his employment by the road, there were expended the following amounts:

Shop machinery and tools, additions and betterments..	$ 732,682
Shop machinery and tools, maintenance of equipment..	1,353,996
Total	$2,086,678
Cost of new engines and cars	$15,810,125
Other expenses (a new item of expense)	1,474,210
Increased cost of supervision mechanical department..	765,235
Total of four items	$20,136,248

and these on four items alone, and that during the same period expenditures were equally as liberal in other directions, all kinds of materials and supplies being secured in such quantities as to

insure protection against such emergencies as are liable to arise on a large system under strike conditions.

Consequently, at the time of Mr. Emerson's employment, there were on hand large quantities of finished parts of locomotives, belting, etc., and to make any claim whatever for economies effected on the single item of belting, at one shop only and for one year, without showing the actual purchases, quantity on hand, and issues for a sufficient length of time at all points of the system, not only invites suspicion as to its validity, but excludes any figures produced from the statistical class.

It would be an easy matter for any employee whatever to distribute the stock as to show a reduction in the quantity purchased for one year at one point.

On a certain representative trunk line the operating expenses last year were:

Total	$70,768,251.57
Maintenance of equipment	16,636,145.45
Maintenance of shop machinery and tools	324,420.41
Ratio of maintenance of shop machinery and tools to operating expenses	.0045
Ratio of cost of belting to maintenance of equipment	"Not given"

Somewhere in an expense item that amounts to about two per cent. of the cost of maintenance of equipment and less than one-half of one per cent. of the total operating expenses can be found, by diligent search, the infinitesimal item of belting costs—the alleged economies from which are offered as an endorsement of the Scientific Management of Railways.

With reference to the problems which Mr. Emerson states were demanding solution on the Santa Fe in 1904, I note he quotes the increase of freight business at 40 per cent. and of passenger business at 30 per cent. in three years, this to be handled with almost *no* increase in equipment, and without time to increase shop facilities. These statements do not harmonize very well with the figures shown in the company's annual reports, which are doubtless authentic. These reports contain the following with regard to increased equipment and expense for shop

facilities for three years prior to 1904, and for the years 1904, 1905, 1906, and 1907:

TABLE "K"

Year	No. new pass. cars	No. new engines	No. new freight cars	Shop machinery and tools		Cost of new engines and cars	Cost of maint'nce of equipment superintendence	Other expenses
				Additions and betterments	Maint'nce of equipment			
1901	52	52	1,147	$ 162,572	$ 181,168	$ 992,899	$ 50,742	$ 129,370
1902	65	207	4,972	68,757	283,846	6,807,494	278,228	239,753
1903	19	75	2,231	363,494	401,809	3,548,428	310,016	386,652
1904	60	156	2,640	137,859	487,170	4,461,304	326,217	718,435
1905	20	31	101	137,023	486,620	58,434	367,555	817,055
1906	114	192	5,033	190,198	367,474	8,994,478	446,287	536,356
1907	140	128	5,566	73,981	315,844	8,843,351	599,290	611,744
Tot.	470	841	21,690	$1,133,884	$2,523,931	$33,706,388	$2,378,335	$3,439,365

Total expenditures, seven years	$43,181,903
Average per year	6,168,843
Amount of expenditures 1901 to 1903, inclusive	14,205,228
Amount of expenditures 1904 to 1907, inclusive	28,976,675

From this table it is very clear that, notwithstanding his statement to the contrary, the Santa Fe had increased their number of engines and cars, their shop machinery, tools, and other facilities very materially before Mr. Emerson's employment on the line. Moreover, the same liberal policy was maintained following his employment.

All competent railway officers hold, and Mr. Emerson agrees, that the real measure of transportation efficiency is in reduced cost of transportation, or in greater net earnings, securing a greater return to the shareholders of the property. In the items of locomotive expense, the cost in cents per mile or the cost in dollars per engine per year may advance on account of the increased size of locomotives and the increased cost of labor and material; but when such is the case there should be a correspondingly decreased cost per ton mile for moving freight, resulting from the greater engine capacity.

It is shown in my paper, and I here repeat, that the cost in cents per mile and the cost in dollars per year for the maintenance of locomotives on the Santa Fe was not materially reduced by

Mr. Emerson's methods. It did drop from $4,165 to $3,036 per engine per year on account of the ending of the machinists' strike. Since this drop, however, it has gradually increased. In fact, eight of the principal items in connection with locomotive statistics have increased and only one—locomotive mileage—has decreased. Even with the increased size of locomotives, the cost per ton mile for moving freight has not been reduced to what it was in 1904 by almost 22 per cent. Also, the cost per "road unit" for locomotive maintenance is higher than in 1900.

In order to more clearly emphasize these items of expense, etc., I have reproduced them on the graphic chart L, shown on the following page.

In the presentation of and comments on the Santa Fe statistics (pages 21 to 26 and Table E, page 23 of my paper) the point was established that the reductions in 1906 and 1907 were the result of a return to normal conditions, with the double advantage of freedom from the expensive exactions of shop committees and full benefit of all economies that could be derived from the interrupted introduction of such improved methods as were not possible in the shops prior to the strike.

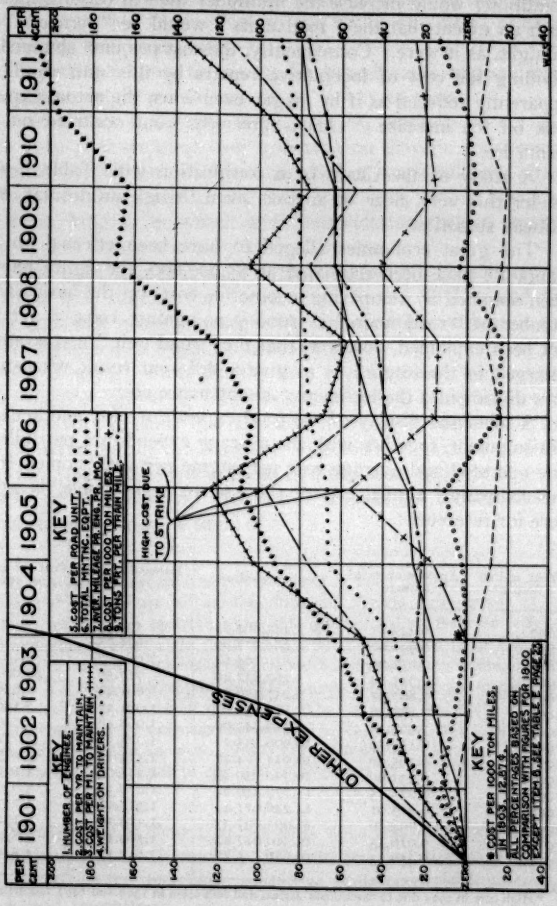
Consequently the unit cost per engine per year or per mile run should have fallen considerably below the costs prior to the strike, since the combined economics, which included some 841 new engines, should have more than offset the increased cost of labor, material, and increased size of locomotives. The cost per 1,000 ton miles should, without question, have shown a marked reduction. That this was not so is clearly shown.

In addition to the points already mentioned, the chart brings out the fact that the term "road unit" used by Mr. Emerson to measure the cost of locomotive maintenance is theoretic and fallacious. The unit is an imaginary one, derived by an arithmetical calculation, thus:

$$\frac{\text{Mileage} \times \text{average weight of drivers in pounds}}{1{,}000{,}000} = \text{Road Unit.}$$

It is at once manifest that the addition of a large number (841) of extremely heavy engines and the retirement of many

GRAPHIC CHART L.



light ones (culling-out, of course, those in the worst physical condition) would increase the multiplier used in this formula to such an extent that the "road units" would be "jumped" out of sight, as it were. Consequently, the cost per unit obtained by dividing the cost of locomotive repairs by this unit would be apparently reduced as if by magic, even when the actual expense was on the increase. This is precisely what occurred on the Santa Fe.

A study of the Chart L in conjunction with Table E will render this very clear to anyone, even though unfamiliar with railway statistics.

The great economies alleged to have been effected on the Santa Fe have been estimated at $5,000,000, the figure having been obtained by comparing locomotive costs on the basis of the number of "road units" in 1906–7 as against 1904–5. It has not been explained, however, that the "road unit" was so much enlarged in the interim as to give a different result when used as a divisor into the locomotive maintenance cost.

A tabulated display of the total expenditure for maintenance of equipment, together with the average expenditure per mile of line operated and average cost per engine per year, copied from the company's annual report 1897 to 1911, inclusive, is given here for reference:

Year ending June 30.	Average operated mileage.	Total expenditure.	Expenditure per mile.	Cost per engine per year
1897.....	6,443.81	$ 3,443,884.82	$ 534.45	.....
1898.....	6,936.02	4,659,277.99	671.75	.....
1899.....	7,032.62	4,810,795.64	684.07	.....
1900.....	7,341.34	5,267,832.40	717.56	$2,096
1901.....	7,807.31	6,257,456.57	801.49	2,858
1902.....	7,855.38	7,864,951.25	1,001.22	3,156
1903.....	7,965.13	8,510,543.09	1,068.48	3,040
1904.....	8,179.59	10,006,135.41	1,223.31	3,772
*1905.....	8,305.40	10,914,864.47	1,314-19	4,165
*1906.....	8,433.99	10,720,040.43	1,271.05	3,101
*1907.....	9,273.15	11,779,846.64	1,270.32	3,036
1908.....	9,415.01	14,246,621.44	1,513.18	3,713
1909.....	9,794.86	13,903,897.37	1,419.51	3,132
1910.....	9,916.33	15,560,047.44	1,569.13	3,832
1911.....	10,350.13	16,686,145.45	1,612.17	4,544

* High cost in 1905 due to machinists' strike, and reduction in 1906 and 1907 following its termination.

To further demonstrate the fallacy of the "road unit" theory as a basis of maintenance cost, attention is invited to the relative weights of certain locomotives on the Santa Fe system prior to and during the period 1905–7.

On June 30, 1905, the Santa Fe owned 1,454 engines, with an average weight on drivers of 50 to 117.29 tons.

Among this equipment there were 89 engines, or 6.1 per cent. only, that weighed over 100 tons on drivers. Moreover, 1,122, or 77 per cent. of the total number, averaged only about 59 tons on drivers, and among these were over 700, or about 50 per cent., Mogul, ten-wheel, and Consolidation freight engines that would average about 65 tons on drivers.

From these figures it must be clear that with a preponderance of such light engines the "road unit" would be low and the road unit cost would consequently appear high, although the actual maintenance might be economical.

Mr. Emerson points out the very low efficiency with which, in his opinion, operating facilities are nowadays being employed, and endeavors to show that this low efficiency is responsible for the construction of unnecessary locomotives, cars, and line; therefore, the investment in these facilities must be considered as unwise or unnecessary. He clearly emphasizes the conclusion in his remarks when he says:

> "American locomotives average about 75 miles per day. A good team of Yukon dogs will go this distance. Freight cars average 25 miles per day. A postman walks this distance daily. A horse will in emergency exert eight times his power. Let us learn from *Dogs* and *Horses* how to maintain high averages and meet emergencies.
>
> "The same law applies to track—more miles than are needed, few trains per day using the track. Who can deny that there is a larger quantity of railroads than needed? The records for 1910 for the United States show eighty-one (81) abandoned railroads. That so many of them fail to pay dividends proves it."

From this it is clear that not only does Mr. Emerson believe our railways to be shamefully mismanaged, but that also a vast amount of capital has been wasted in their construction, equipment, and operation.

Reviewing in detail Mr. Emerson's criticisms epitomized in the foregoing syllabus form:

American passenger locomotives regularly make from 50 to 70 miles per hour with trains of from 300 to 500 tons in weight, while heavy freight engines make from 100 to 150 miles per day with trains varying from 2,000 to as high as 6,000 tons in weight. The low general average mileage of all locomotives quoted is secured by dividing the total mileage of all locomotives owned, which includes thousands of engines standing in shops receiving repairs, held to go in shops, or in good order, but held ready for emergency use.

If the mileage made by all the dogs in the United States and the high-speed dogs in Alaska were averaged on the same basis as that of the locomotives—that is, by equating the tonnage—it is safe to say that the average dog mileage per day would be less than two miles. Also, if the power exerted by all horses were similarly averaged, it would likely indicate less than one-half horsepower as an average. The average performance of the inhabitants of the United States would, too, probably be less than one-quarter their full capacity.

The apparent low average of freight cars is arrived at by Mr. Emerson in the same way as that of the locomotives, and, on analysis, reflects more unfavorably on the patrons of the carrying lines than on the management.

The admonition that we learn from "dogs and horses" how to maintain high averages is nothing more nor less than an admission that "Scientific Management" would, if forced on American railways, practically subject all employees to conditions similar to those under which, as the slave of man, a horse develops eight times its normal power or a Yukon dog team travels 75 miles a day. Neither the officers nor employees of American railways will ever consent to the adoption of any plan or scheme that is predicated upon a standard of efficiency established by dumb brutes under the lash.

Passing from the items of locomotives and cars, we are next told by Mr. Emerson that there are too many railroads, and that 81 roads were abandoned in 1910.

As a preliminary to taking up the main points in regard to abandoned lines, I will enter the following table of railway

mileage by years, from 1890 to 1910, with ratio per 100 square miles of country, etc.:

TABLE SHOWING MILEAGE.

Miles of line per 100 square miles territory, total of all mileage, and per cent. of increase over 1890.

	Miles of line.	Miles of line per 100 square miles of territory.	Total mileage all yards and other tracks.	Per cent. of increase over 1890.
1910	239,652	8.07	348,909	67.2
1905	217,018	7.34	306,798	42.2
1900	192,941	6.51	258,784	24.5
1895	179,176	6.08	236,894	13.5
1890	159,272	5.51	208,612	....

Comparative mileage, and mileage per 100 square miles of territory, in nine (9) different countries.

	Miles of railway.	Miles of line per 100 square miles.
Belgium	5,038	44.3
Great Britian and Ireland	23,103	19.1
Germany	36,601	17.5
Switzerland	2,814	17.5
Netherlands	2,240	15.1
Denmark	2,160	14.5
France	29,836	14.5
Austria-Hungary	26,434	10.1
United States	239,652	8.07

From the first table it will be observed that the total mileage has increased 67.2 per cent. during the past twenty years. Nevertheless, the ablest authorities on this subject have repeatedly gone on record as having stated that we are badly in need of many billion dollars' worth of additional tracks, yards, terminals, shops, motive power, equipment, etc. Mr. Emerson now says there is too much mileage.

A further and clearer analysis of this point is made by considering the number of railways that underwent changes during the years 1908 and 1909, and from the following table given it should be possible to draw definite conclusions:

SUMMARY OF CHANGES IN LIST OF RAILWAYS

During the years 1908 and 1909.

Class.	1908			Average length in miles.	1909			Average length in miles.
	Number.	Line owned miles	Line operated miles		Number	Line owned miles	Line operated miles	
Reorganized.....	7	230.30	166.86	23.83	1	42.51	42.51	42.51
Consolidated....	15	1,130.53	696.04	46.40	10	287.68	285.00	28.50
Merged.....	39	1,345.73	471.65	12.02	63	9,812.76	2,260.74	35.78
Name changed...	3	57.25	64.43	21.71	5	52.03	47.75	9.55
Abandoned.....	30	305.09	260.75	8.69	29	258.38	189.38	6.53
Miscellaneous....	33	616.06	621.76	18.84	47	823.80	877.20	16.53
Total.....	127	3,684.96	2,283.49	17.98	155	11,257.16	3,702.58	23.88

Total mileage in United States, 1909	342,351	
Miles abandoned	260	
Per cent. of total		.07
Miles of line added in 1909	8,705	
Miles abandoned in 1909	260	
Net mileage added in 1909	8,445	
Per cent. mileage added in excess of abandoned companies		3.248

Three thousand two hundred and forty-eight per cent. more lines were added than were abandoned, and the ablest authorities still say we need billions of dollars for more tracks, etc.

It is clear from the table that the number of lines abandoned does not in the aggregate represent very much mileage. The average length of each line abandoned in 1908 was 6.53 miles, while in 1909 it was 8.69 miles. In the absence of details, though, Mr. Emerson's statement might lead one to think that the railway business in general was so unprofitable that it was rather rapidly being discontinued.

It should also be borne in mind, in connection with these figures, that in the development of industries along the railway lines it is not an uncommon practice for the railway company

to assist private capital by constructing a branch line leading out to a mine, lumber camp, etc., that will not only serve to assist the development of the country, but will also provide additional tonnage for the road. It is not infrequently the case, too, that small lines so incorporated and operated very profitably for some years become unnecessary after the mine has become exhausted or the lumber cut off.

In other cases the corporate name is discontinued, a small road being taken over by a larger line with which it connects. While the records would show the number of such lines as having been abandoned, a close analysis of the mileage in the different States would reveal the facts of the case.

The same is also true of short electric lines, intersecting a main steam railway at two points and running parallel to it between those points. On the taking over of these by the steam line their mileage is, of course, added to that of the purchasing company. Therefore, the plain statement that 81 railways were abandoned in 1910 is misleading.

As further evidence on the question of mileage, I would invite attention to the following table of new mileage added to railways in the United States during the years given:

Year.	Mileage added.
1906	5,425
1907	5,362
1908	3,918
1909	6,310
1910	3,751

or a total of 24,766 for the five years.

To this may be appended the statement that 3,066 miles were built in 1911 by 146 different companies.

With respect to the question of dividends or returns on invested capital of railways, it is quite true that many lines have not paid dividends. In 1909, 35 per cent. of the stocks failed to yield a dividend, while approximately 59 per cent. yielded returns of from 2 to 10 per cent. and about six per cent. (to be exact, 5.95) yielded more than 10 per cent. dividend.

The lines yielding no returns were usually located in a territory where public sentiment—influenced by the attitude of those who so continually point to the railroads as examples of mismanagement—has been so embittered against the roads as to

render economic operation very difficult, if not impossible. The result is a matter of no great surprise.

In referring to the question of locomotive fuel, Mr. Emerson says: "In various tests made as to freight, passenger, and switch locomotives, coal consumption has been found to be *three* times what care and supervision could reduce it to."

In other words, $123,018,000 of the $184,527,000 paid for locomotive fuel is practically wasted.

I have already touched on some points in regard to fuel economy in reply to Mr. Going, and therefore consider it unnecessary to enter into further details on this subject.

The record of fuel used on the test run on the Lehigh Valley Railroad on June 21, 1911, referred to by Mr. Emerson, does not represent the average conditions in railway operation by any means; neither do the results of runs on other lines that he quotes support his claim that two-thirds of the fuel now used is wasted. The Lehigh Valley test record shows only the fuel used on a *special* run, in which one engine handled a train 466.6 miles under conditions it would be impossible to duplicate in ordinary every-day practice.

Therefore this comparison is of no value so far as locating fuel wastes and defining a practical remedy therefor are concerned, since, to draw it, is tantamount to saying that fuel per ton or car mile in excess of this amount is wasted, and no statement could be further from the known facts.

THE BONUS SYSTEM.

What might be termed the "acid test" or ultimate analysis of the bonus system, the main feature of Scientific Management on the Santa Fe, are the all-absorbing questions: Does it actually save money? If so, how much? Are the savings effected on certain operations more than offset in others, the ultimate result being a higher cost?

Mr. Emerson details the various costs of *certain operations* on the Santa Fe to support his claims of great savings to the *whole* company.

In my paper no mention is made of the amounts paid out by the Santa Fe in bonuses, for the reason that figures I received on these were given me in confidence. Mr. Emerson having relieved me of any necessity of betraying confidence, however, by

making public this item of expense, I am at liberty to discuss this feature without embarrassment.

That there may be no misunderstanding on the part of anyone as to what the $1,283,000 a year expenditure on account of bonus payments and supervision in 1910 was really for, it might be explained that, under the bonus system, a price or time limit is put on each operation performed, and a premium or bonus is paid the mechanic or operator for accomplishing the work in a less time than specified. This premium is sometimes extended to those in charge of the work. So far it sounds all right.

Actually, however, the plan works out as follows:

The workmen, spurred on to their maximum speed by the money prize offered and finding willing allies in the person of the men in charge who jointly profit, cannot fail to slight repair operations. The initial high-speed operations usually pave the way for an early repetition, and not infrequently necessitate more extensive repairs in the end. All this results in an excessive cost for maintenance.

Railway managers and departmental heads are eagerly seeking for and adopting plans whereby the unit cost of any operation or service can be lowered. Railway security holders are interested in knowing how much less is the cost per engine per year, or per mile run, or per ton mile on this line that Mr. Emerson offers as an example of the result of such adoption, than on other lines.

It is of little comfort to shareholders to read that a passenger engine has run 234,896 miles between shopping, and then find, on inquiry, that the cost per engine that year (1910) was $3,832, or 12.87c. per mile, and the next year was $4,544, or 15.80c. per mile, while on another line, operating with heavier power but making less than 100,000 miles between shoppings, the cost per engine per year and per mile was much less.

It is beyond the range of possibility to suppose that in America the laboring classes will submit, without protest, to the introduction of any plan or system which in its operation discriminates in favor of the man of maximum efficiency or in any manner abridges personal initiative in any line of human endeavor. Both intellectually and in point of numbers they are in a position to, and probably would, show their resentment, if pressed, in a manner not pleasant to contemplate.

The proposition of saving $730,000,000 a year on American railways without speeding up every employee to the limit of 100 per cent. efficiency and without discharging a solitary man will not be given even passing consideration by the one and three-quarter million railway employees, and will be promptly discredited by the majority of more than 91,000,000 people our railways serve.

Making the claim that Scientific Management elevates the class of the workingman both socially and financially might properly be termed "sugar-coating a very bitter pill," to enable it to be forced down the throats of their employers by the managements.

The practice has been, and is now, to treat the class of working people no better than is necessary in order to avoid difficulties, and whenever an employer can substitute machinery for men he immediately does so, proving that he uses men as a means of contributing to his interests only, and deals with them as with a common commodity or article of commerce.

Contra to the above, the employees, particularly the more strongly organized ones in railway service, have in recent years not only done much themselves to improve their financial and social condition, but have in many instances gone to the extreme of making unreasonable demands. The general trend has been towards increased compensation and lessened hours, even when the plant was already operating at a loss. Consequently there has been, and now exists, a condition calling for a line of demarcation between how far the employees may swing the pendulum in one direction and the employers in the other if departure must be made from its position of rest.

This latter is becoming more serious each year, and as combinations of capital and labor increase, the solution of problems arising between them will call for ablest talent on both sides. As men grow more conscious of their birthright of personal dignity, the situation will, in all lines of human endeavor, become more intensified.

DETAILS OF UNIT COSTS ITEMIZED.

The various items of unit costs of certain operations, of hours worked, etc., with discussions thereon, given by Mr. Emerson, would be of some interest if in the end any net economies

were shown; but, as the expenses of the railway company in question were constantly on the increase all along (except when reduced by the ending of the strike), quotation of these items only tends to weaken the claims of economy. The several tables given in my paper and in this reply to Mr. Emerson evidence this, and more than cover the ground.

The question of increased size of power on the Santa Fe having been mentioned by other speakers, I will, at the risk of trespassing on valuable time, give one last example in this connection.

Take the Great Northern Railway Company, which is a heavy freight-carrier in the northern range of the Rocky Mountains, where the winters are severe, rendering operation more costly than in the milder climate of the South. This line has a greater number of Mallet locomotives than any other line in America, if not in the world. It has, however, not yet employed the Scientific Management methods herein referred to.

Anyone would feel safe in surmising that on this railroad the cost for locomotive maintenance would be higher than on the Santa Fe. That this is not the case, though, is shown by the following table of last year's figures:

1911.

	Number of engines and cost per year and mile to maintain.			Average tractive power and weight on drivers.		No. Mallet engines	Total cost to maintain engines.
	No. Eng's.	Cost per year.	Cost, cents.	Tractive power.	Weight on drivers.		
Great Northern..	1,169	$2,300	9.57	33,249	140,000	103	$2,688,000
Santa Fe.....	1,997	4,544	15.80	30,829	132,000	58	*5,311,000
Per cent. Santa Fe above...	.....	93.65	54.60	.....	.....	...	.....

*For an equal number of engines.

Again, as so much stress has been laid on the increased cost of maintenance due to the purchase and use of Mallet engines, it might be stated that the average cost per engine per year (including 103 Mallets) on the Great Northern for 1910 was only $2,843.

Using this figure as a standard for comparison with all the

Santa Fe engines except the Mallets, of which latter they had only 35 at the time, we get the following:

Great Northern (1910)....Engines, 1,118; cost per engine	$2,843
Santa Fe (1910).....Engines, 1,923; cost per engine	3,832
Santa Fe (less 35 Mallets)..Engines, 1,888; $2,843 each	5,367,584
The cost of locomotive maintenance in 1910 (see Table E, page 19) was	$6,896,894
Less cost of light engines on Great Northern basis.....	5,367,584
Leaving for the Mallets a remainder of.....	$1,529,310
This, distributed on 35 engines, amounts to	43,694

If the cost per engine per year on all engines except Mallets on the Santa Fe had even been down to that per engine per year on all engines on the Great Northern, the amount spent on Mallets would still have been $43,000 per year.

From all view-points, then, it is impossible for Mr. Emerson, or any other advocates of Scientific Management, to show that the system under consideration has enabled the Santa Fe to maintain its engines at a less cost than on other lines not employing the system.

CONDENSED OR SHORT MILEAGE MOST ECONOMICAL TO MAINTAIN.

It is frequently pointed out, and with a certain amount of justification, that the longer the line, and consequently the more scattered the operating units, engines, shops and forces, the greater is the maintenance cost. These items can quite properly be compared for the two roads just considered:

1910.

Roads.	Mileage	Number engines and miles to each engine.		Cost of supervision and ratio per mile.	
		Engines	Miles to each	Superintendence	Ratio
Great Northern....	7,726	1,118	6.46	$178,544.78	$23.10
A., T. & S. F.....	9,961	1,923	5.12	534,564.48	53.66
Per cent of miles to each engine on Great Northern over Sante Fe.....			24.6	Per cent. cost per mile Santa Fe over Great Northern..	132.29

It may be observed that the Great Northern power is scattered or spread over 24.6 per cent. more territory per unit than the Santa Fe, and although the average tractive power of the Great Northern engines is above that of the Santa Fe, and the Great Northern owns and operates twice the number of Mallet engines, it may also be observed that its ratio per mile for cost of superintendence maintenance of equipment is about 132 per cent. less than the Santa Fe.

The matter of additions, betterments, etc., to locomotives, cars and shops, etc., has been in progress on most, if not all, trunk lines during the past ten or fifteen years, and it is therefore fair to assume that the amount of expenditure on this account will compare favorably on lines handling practically the same character of business. So that it would seem proper to suggest that the Great Northern figures on cost of maintenance of locomotives are indicative of a very high degree of efficiency in its mechanical organization, while its overhead charge, or expense for supervising its mechanical department (see Table F, page 21), reflects freedom from the unproductive labor and bonus costs on the Santa Fe.

The very able and enthusiastic advocates of Scientific Management might well take heed of some notable examples of men of more than ordinary scientific or professional ability that made a sorry mess of certain practical problems in the engineering line.

Dr. Dionysius Lardner stands out prominently as an example of a great scientist and mathematician who was believed by some to have been a great engineer.

When marine engineering was in a state of development inviting co-operation and assistance from all interests, Dr. Lardner conceived the idea that he was not being consulted by everyone interested in the question, and therefore decided the proposition was a failure. He proceeded to inform the public in general that the men in charge of the development of this form of transportation were notoriously inefficient.

Dr. Lardner stated, in 1835, that it was as feasible to cross the Atlantic Ocean by steamboat as it was to take a trip to the moon. This was sixteen years after a partially equipped steam vessel, the *Savannah*, had already crossed!

Now the statement is made that the present wastes on our

railways due to inefficiency are $730,000,000 a year. The following table shows these figures in their relation to the amount per capita of our national debt, railway employees, railway shareholders and officers:

Items	Amount in money	Classification		Amount per capita
National debt . . .	$926,982,773.55	U. S. population	91,000,000	10.16
Railway wastes . .	730,000,000.00	Railway employees . . .	1,502,000	486.03
Railway wastes . .	730,000,000.00	Railway shareholders .	1,000,000	730.00
Railway wastes . .	730,000,000.00	Railway officers	13,514	$54,018.00
Less average yearly compensation to officers				2,502.00
Average yearly preventable net waste chargeable to each officer				$51,516.00

Time required for alleged railway wastes to offset national debt, 1 year 3 months 8½ days.

It may be of interest to note that if each officer were held responsible for an equal share of the $730,000,000 which Mr. Emerson claims is being wasted, the deficit charged to each would be over $50,000. It is the publication of such visionary propositions as this that poisons the public mind.

In closing, the following extracts from the editorial comments of the principal railway paper of this country will make it very clear to all that there is not the slightest similarity between the methods employed in securing that high standard of efficiency essential to a well-operated railway and the alleged newly-discovered Scientific Management:

"THE EFFICIENCY ENGINEER."

While we have taken great pains to advise our readers frankly of the mistakes that have been made by the efficiency engineers, we have taken equal pains to reiterate, time and again, our belief in the importance of giving more thought to the principles underlying efficient work.

The danger of this discussion, as we have said before, is that some managers may be deluded into thinking that the efficiency engineer, or some of the features commonly connected with Scientific Management, will be the panacea for all his troubles, and will jump from the frying-pan into the fire.

When the system craze spread over the country, a number of

years ago, many concerns who rushed into the introduction of it on a large scale overdid it, and not a few of them were forced into bankruptcy. A certain amount of it proved to be a good thing, but the employment of some of the system engineers, who sprang up like mushrooms in a night, proved to be anything but advantageous. It is curious to watch the rapid development in a similar manner of the crop of efficiency engineers (at least they call themselves such), many of whom have had practically no experience and can lay little more claim to the title than that they have read a book or two on the subject.

The fads and fancies that have been adopted in manufacturing or railway shop, then dropped like hot cakes, remind us of Ponce de Leon in his search for the Fountain of Youth. What a scrap heap some of them made!

Just as the electric engineers disagree among themselves on the best methods of electrifying railways (and so many good engineers believe trunk lines will never be electrified), so the efficiency engineers each seem to distrust the other. Taylor, Gantt, Emerson, Barth, and Morrison in many instances actually contradict each other.

The articles on the mistakes of efficiency men suggest that some of them, who placed themselves in the limelight during the past few months, have been extremely careless in their statements. A railway officer, who is a keen student of men, in speaking of one of these efficiency engineers said recently:

> *As an expert statistician and a dreamer of lofty ideals he has few, if any, equals. Those who know him best regard him as one possessed of a born gambler's instinct. Not necessarily faro, roulette, or poker, but in taking long chances on making statements that neither he nor anyone else can substantiate, and trusting to Providence that they will be accepted without verification.*

A saving of 5 per cent. on 25 per cent. of a machine shop payroll in railway operation, where the entire mechanical department expense is only about 20 per cent. of the total operating expense, is hardly to be classed with the extravagant claims persistently made in the past few months with respect to the management of railway properties by this plan.—*Railway Age*, April 7, 1911.

The railways need much assistance in many ways, and, as stated in the closing paragraph of my paper, the greatest help to those charged with the responsibility of management would be a combined effort on the part of all to introduce the more liberal policy of friendly feeling towards them, instead of holding them up before the public as examples of wasting by mismanagement several hundred million dollars a year.

20,000-Kilowatt Turbo-generator at New York Edison Company's Station. (*Elect. Rev. and West. Electn.*, lix, 967.)—The turbine is of the vertical type built by the General Electric Company. The base dimensions are 17 feet 6 inches by 17 feet; height above floor, 35 feet 7 inches; height of foundation above basement floor, 10 feet; area occupied, 279 square feet; nominal rating of turbine, 30,000 horsepower; diameter of wheels, 13 feet; total number of wheel buckets, 7,200; approximate bucket velocity, 6 miles per minute. The generator is of 4-pole, 3-phase, 25-cycle type, operating at 6,600 volts, 750 revolutions per minute. Capacity, 20,000 kilowatts. Steam consumption, guaranteed, at 175 pounds pressure by gauge, 28.5 inches vacuum, superheat 100° F., is as follows:

Load in K. W.	Steam, pounds per K. W. an hour.	Total steam per hour, pounds.
10,000	15	150,000
15,000	14.4	216,000
20,000	15	300,000

Each turbine requires 400 tons of coal per day; 86,000,000 gallons water for condensing, and 80,000 cubic feet per minute of air for cooling the generator windings. Three turbine units occupy a space formerly taken up by four 3,500-kilowatt engine-driven units. The Waterside stations of the New York Edison Company have a capacity of 500,000 horsepower. They have a total of 1,114 miles of mains, feeders, and cables in their underground system, and supply electric energy over twenty-one square miles of Manhattan and about forty square miles of the Borough of Bronx.

The Calcium Carbide Industry. (*Times, Eng. Suppl.*, Dec. 27, 1911.)—In the choice of a site for a carbide factory the chief factors which have to be considered are cheap supplies of raw materials, lime or limestone and coke or anthracite, and of power. Most of the large works have been established in places where a practically unlimited supply of water power is available, especially in Norway, where there are also large deposits of limestone. The limestone must be free from magnesia, and especially from phosphorus compounds. Rather more than the theoretical amount of lime is used, *viz.*, 2,000 pounds of lime to 1,200 pounds of anthracite per ton of carbide. The manufacture is conducted in electric furnaces provided with two inclined electrodes capable of maintaining a temperature of about 3,038° C. (5,500° F.). In a modern works a furnace takes about 1,500 kilowatts, and produces 50 to 60 tons of carbide per week. On a moderate scale the power consumption is estimated at about one electric horsepower per year per ton of carbide, but in very large installations the power consumption is much lower. For example, at Odda more than 30,000 tons of carbide are produced per year by six turbo-alternators of about 4,000 horsepower each, and one of these serves as a stand-by.

NOTES FROM THE BUREAU OF STANDARDS.

DEFLECTION POTENTIOMETERS FOR CURRENT AND VOLTAGE MEASUREMENTS.[1]

By H. B. Brooks.

In the deflection potentiometer the galvanometer is normally deflected, due to the passage of the current through it, instead of being merely a null instrument, as was formerly the case with potentiometers. Previous work of the author [2] is extended and generalized so that the same instrument may be used for both current and voltage measurement, and two new models are described. The general theory has been worked out in detail.

The design of the deflection potentiometer requires such an arrangements of circuits that the current through the galvanometer is properly taken account of, and that the sensitivity of the galvanometer be the same whatever the dial setting. This is most easily accomplished by arranging for a constant total resistance in the galvanometer circuit.

In these new models, pivoted galvanometers, as well as the regulating rheostats for the battery circuit, are built into the potentiometer. Two pairs of binding posts are provided for convenience, one for current and one for voltage measurements, arranged for connection to shunts and volt boxes, respectively. A double-throw switch enables one to change very quickly from one to the other, and a second switch admits of a similar change from the unknown emf. to the standard cell without changing the dial setting. A dial is added which allows the use of any unsaturated Weston cell whose value is from 1.0180 to 1.0190 volts inclusive. The galvanometer key has a protective resistance which is cut out on full depression. Each model has but a single dial, the last three figures being read by deflection of the galva-

[1] Bureau of Standards, Reprint 172.

[2] *Bull. of Bureau of Standards, 2*, p. 225, 1906. (Reprint No. 33) *4*, p. 275, 1908. (Reprint No. 79).

nometer. Both instruments were built by Leeds & Northrup, and the galvanometers by Weston.

In "Model 3," which was designed for general laboratory and testing work, the main dial has 30 steps of 0.05 volt each, and the galvanometer may be read to 0.0001 volt, or 1/15000th of full scale. For current measurements ordinary precision shunts may be used, but for voltage measurements a special volt box is required; convenient values of the ratio adopt the instrument to 3, 15, 30, 75, 150, and 300 volts.

"Model 5" was designed especially for photometric work, and is a high-resistance instrument in order that the correction for the current taken by the volt box may be small.

The instruments are sensitive to less than 0.01 per cent. of full scale reading, and the precision is at least 0.03 per cent. They are thus intermediate between deflection instruments and standard null potentiometers, having ten times the sensitivity of the former and one-tenth that of the latter. This makes them especially well adapted for commercial and engineering measurements, calibration of instruments, etc., as, requiring no external galvanometer, they may be carried from place to place, are not subject to stary field errors, and may be used on fluctuating voltages, as the galvanometer is quick and critically damped.

P. G. A.

OUTLINE OF DESIGN OF DEFLECTION POTENTIOMETERS, WITH NOTES ON THE DESIGN OF MOVING COIL GALVANOMETERS.[1]

By H. B. Brooks.

THE galvanometer is the central and important feature in the design; its constants determine what can be obtained in the way of sensitiveness of reading, speed of working, resistance of volt box, and resistance of the circuits. The total resistance in the galvanometer circuit should have the proper value for the condition of critical damping. This is a frequently neglected but very important galvanometer constant.

One will usually try to adapt some existing type of galva-

[1] Bureau of Standards, Reprint 173.

nometer, using it as a starting point and making changes until proper constants are obtained. A regular procedure is developed for this purpose, starting with proper values of torque and weight, and taking into consideration the flux density in the air gap, length of air gap, number of turns on moving coil, size of coil, area and shape of pole pieces, etc. The total critical resistance should be from five to ten times the coil resistance, and the period should be short, 1 to 1.5 seconds. This calls for a rather high value of the flux in the air gap, from 1,500 to 2,000.

General formulas are developed for the design of deflection potentiometers, and as a numerical example the complete design of the 1.5-volt instrument described in the previous paper is worked out in detail. P. G. A.

RESISTANCE COILS FOR ALTERNATING CURRENT WORK.[1]

By H. L. Curtis and F. W. Grover.

IN an ideal resistance coil for alternating current work two requirements need to be fulfilled in addition to those which are of importance in direct current work, *viz.:* (1) the resistance must be independent of the frequency, and (2) the phase angle must be zero. Many of the resistance coils in use at the present time do not even approximately fulfil these conditions. This paper attempts to set forth the principles which must be followed in the construction of satisfactory resistance coils for alternating current work, and to show how to apply them to the design and construction of several coils of different denominations.

The most important thing in the design of a coil whose phase angle is to be small is to wind it in such a way that its inductance will be a minimum. However, there are three other effects which need to be considered in the discussion of the phase angle, viz., (1) "skin effect," (2) capacity between the wires, and (3) absorption in the dielectric between the wires. Each of these three causes also gives rise to a change in the effective resistance of the coil when used with different frequencies of alternating current.

Formulas have been developed for computing the value of the

[1] *Bulletin of the Bureau of Standards,* Reprint 177.

"skin effect." By means of these it can be shown that, with the size of wire usually used with coils having a resistance of one ohm and larger, the "skin effect" is in all cases negligible.

The capacity between the wires is in parallel with their resistance and inductance, and is distributed along their length. If R' is the effective resistance of a bifilar coil and its phase angle, then to a first approximation

$$R' = R\left[1 + p^2C\left(\frac{1}{3}L - \frac{2}{15}CR^2\right)\right]$$

$$\tan\vartheta = \frac{p\left(L - \frac{1}{3}CR^2\right)}{R}$$

where R is the ohmic resistance of the coil, L its inductance, C the capacity between the two wires, and p is 2π times the frequency. From this we see that $R' = R$ and $\vartheta = 0$ only under the condition that both L and C are zero. While this cannot be accomplished in practice, yet if L is made as small as possible and if $L - CR^2 = 0$, then the phase angle will be zero and the change in resistance with frequency negligible. With coils having low resistance (less than 10 ohms) it is difficult to make the capacity large enough to make $L - CR^2 = 0$; but with coils of high resistance (1,000 ohms and over) the capacity is usually much larger than it should be. Between these extremes satisfactory coils can be constructed without great difficulty.

In case alternating current is used, the absorption of a poor dielectric between the wires may produce an apparent leakage between turns where the direct current insulation resistance is sufficiently high. The magnitude of the effect of this upon the resistance of the coil will depend upon the resistance of the coil and upon its capacity as well as upon the absorption. Hence, while it is entirely negligible for coils of low resistance, it becomes of importance in coils of high resistance. By so designing the coil that the capacity is small it may usually be made negligible.

By keeping in mind the facts which are stated above, it has been found possible to design coils of denominations from 0.1 to 10,000 ohms in which the change in resistance is less than a part in a hundred-thousand for frequencies up to 3000 cycles per second, and in which the phase angle is not more than 3.5′ at

3000 cycles. For tenth-ohm, one-ohm, and ten-ohm coils strip manganin, wound in a bifilar manner, is used. For hundred-ohm coils a single-layer bifilar winding is satisfactory. For thousand-ohm coils fine 200-ohm bifilar coils are wound on an insulating spool (porcelain is satisfactory) and connected in series. For 10,000-ohm coils a special winding was devised. A tube of biscuit porcelain is cut along a diameter for two-thirds of its length. The winding is then made as follows: One turn is made with a single wire, then the wire passed through the slit, and a turn made in the opposite direction. The wire is then passed through the slit and the third turn is made in the same direction as the first, and the process repeated until sufficient wire is upon the spool.

METHODS FOR THE MEASUREMENT OF THE EFFECTIVE INDUCTANCE OF RESISTANCE COILS.[1]

By F. W. Grover and H. L. Curtis.

IN the measurement of inductances which are associated with relatively high resistances, such as resistance coils, the multipliers of voltmeters and wattmeters and the like, the ordinary methods using alternating current of suitable frequency give sufficient sensibility, but they fail to give an accurate determination, due to the fact that the inductance of each arm of the bridge is of the same magnitude as the inductance to be measured. The method which we have used to overcome this difficulty is to substitute for the unknown inductance an inductance of approximately the same resistance, but of such a form that its inductance can be computed from its dimensions. From the changes in the bridge which it was necessary to make to restore a balance, the difference in the inductance of the two resistances was computed.

Three bridge methods were used. The first was Maxwell's method of comparing an inductance with a capacity; the second was Anderson's modification of the above; the third was the use of a variable inductance in one of the arms. These methods gave concordant results, and the method to be chosen in any given case will largely depend upon the value of the resistance associated with the inductance which is being measured.

[1] *Bulletin of the Bureau of Standards*, Reprint 175.

The standards used were in the form either of parallel wires or of circles. Only in the case of one-ohm coils was it practicable to use both forms. The agreement between the two forms was satisfactory, as is shown by the following example. The difference in the computed values, after allowing for the inductance of the binding posts, was 128×10^{-9} henry. The measured difference in the inductance was also 128×10^{-9} henry. With standards having larger resistance different sizes and lengths of wire were sometimes used, as well as different distances apart. As an example the 5000-ohm parallel wire standard was measured with the wires 2 cm. apart and again with them 10 cm. apart. The observed difference was 114 microhenrys. The computed difference, when taking into account the distributed capacity between the wires, has 110 microhenrys.

While in all cases the standards were adjusted to have nearly the same value of resistance as the coil to be measured, yet it was necessary to be able to vary the resistance through a small range without varying the inductance. This was accomplished by two different devices. Steps of a tenth of an ohm were obtained by substituting for manganin links copper links of the same size and form. A continuous variation of resistance from 0 to 0.1 ohm was obtained by means of a copper wire sliding in a tube of mercury. The change in inductance was very small in this case, but where small inductances were being measured it was necessary to make a correction on this account.

The chief difficulty encountered was with coils of high resistance where the capacity between the wires appreciably affects the effective inductance. If L is the computed inductance, C the capacity between the wires, and R their resistance, then the effective inductance L' is approximately given by the equation

$$L=L-1/3\,CR^2.$$

In commercial resistance coils having resistances of 100 ohms or over the last term is usually the larger of the two, so that the effective inductance is negative. With coils greater than 1000 ohms the actual inductance is usually a negligible part of the effective inductance, so that the value of the effective inductance depends chiefly upon the capacity and resistance. With parallel wires the capacity not only depends upon the relative positions of the two wires, but upon their potential with respect to the

earth. The capacity as usually computed requires that the potential of one wire shall be as much above earth potential as the other is below earth potential. To make sure that this requirement is fulfilled in practice, a special network is arranged in which there are two indicating instruments, both of which must show zero current. Although somewhat complicated, this method gives satisfactory results in those cases where the capacity to earth is an important factor.

The methods here outlined have been found to give satisfactory results with resistances from 1 to 10,000 ohms. With coils, the resistance of which lies between 1 and 1000 ohms, it was possible to measure the inductance with such accuracy that the error in the time constant (L/R) deduced from this measurement is not more than 10^{-9} second. For coils with a resistance of more than 1000 ohms the corresponding limit is 10^{-8} second.

HELIUM TUBES AS LIGHT STANDARDS.

By P. G. Nutting, Bureau of Standards.

THE investigation of the properties of electrically conducting gases with a view to their possible use as primary standards of luminous intensity has been in progress at the Bureau of Standards for the past six years. A summary of the results obtained is given below; this includes a report of a recent reproducibility test here given for the first time.

Of the available gases and vapors, helium is the only one emitting light of a suitable color and having reasonable lasting qualities. The light is of a yellowish-white approximately that of the Hefner flame and of an old type carbon filament glow lamp. The useful life of a helium tube is from 5 to 100 hours, depending on its construction and operation. The next best gases would be carbon dioxide and sulphur, but these emit a snow-white light and disappear rapidly in carrying a current.

The form of tube found most suitable has a capillary portion of 2-mm. bore, 2-mm. thickness of wall, and about 7 cm. long. The terminal bulbs are 35 mm. in diameter and spherical, while the electrodes are aluminum disks 1 mm. thick and 25 mm. in

diameter. Recent results indicate that possibly a slightly increased bulb diameter might give longer life to the tubes.

The relation between current and light emitted is very nearly linear over a wide range of intermediate currents, 10 to 35 m.a. Twenty-five milliamperes was chosen as the most suitable standard current.

The ratio of light emitted to internal energy, current times potential gradient, is not quite constant. The minimum watts per candle for a tube of 2-mm. base, namely, 3.8 w./c.p., occurs at a current between 25 and 30 m.a. Owing to the large and uncertain variations in the potential gradient and the difficulties in its precise determination, attention was directed toward expressing light in terms of current and bore rather than in terms of internal energy.

The light emitted by a helium tube as a function of current was later determined line by line for each of the six prominent spectrum lines. These all behave nearly alike, increasing with current sensibly as does the total light. Helium shows no trace of any secondary spectrum in the visible region.

Neither the voltage nor frequency of alternation of the exciting current affects the light emission by a measurable amount. Voltages of 1, 2, 5, and 10 thousand were used, and direct, alternating 60-cycle and 900-cycle current.

Gas density does not affect the specific light emission over a range from 3 to 8 mm. pressure, provided the bore of capillary is not much over 2 mm. With 25 m.a. current through 2 mm.-bore, the light is sensibly independent of gas density from 3 to 8 mm. pressure. Chiefly for this reason these specifications and 4 to 7 mm. pressure were adopted for the standard tubes, inasmuch as gas density is difficult to control and determine in such tubes.

The correction to the light emitted by a centimetre length of capillary for slight departures from 2 mm. in the bore was carefully determined. It is -0.010 c.p./cm. for each $+0.1$ mm. difference in bore from 2.00 mm.

A test for reproducibility was made on a set of forty tubes. The capillary portions of these tubes were specially prepared and selected by Baudin to secure the utmost possible uniformity of bore and wall and freedom from striations. The tubes were made up and filled at the Bureau of Standards.

Color reproducibility was determined by intercomparing the spectra of these tubes line by line with a spectrophotometer. The slight variations observed were well within the errors of observation.

Photometric observations on the mean horizontal candle-power per centimetre length of capillary were made by four experienced observers. The computed probable error in the c.p./cm. for all observers and all the tubes was 0.16 per cent. The average deviation of the tubes from their mean value was 1.15 per cent., the maximum deviation 3 per cent. The four different observers read on an average 1.2 per cent. below, 0.1 per cent. above, 1.5 per cent. above, and 0.5 per cent. below the mean of the four.[1]

THE EFFECT OF ADDED FATTY AND OTHER OILS UPON THE CARBONIZATION OF MINERAL LUBRICATING OILS.[2]

By C. E. Waters.

THE author determined, by a method published some time ago,[3] the relative amounts of "carbonized" matter formed by heating two similar mineral engine oils and mixtures of these oils with various fatty oils, soap, asphalt, sulphur, etc. Samples of 10 grams each were heated in Erlenmeyer flasks to 250° C. for 5 hours. The flasks were carefully matched in size, for it was shown that the "carbonization" is an oxidation phenomenon, depending in amount upon the area of the oil surface exposed to the air. The flasks were heated in a special air-bath so arranged as to allow perfect freedom of diffusion of oil vapors and air.

The loss by evaporation was first determined; then measured volumes of petroleum ether were added, and next day the "carbonized" material which was precipitated was filtered off, washed free of oil with petroleum ether and weighed. The flasks were also weighed to determine the amount of "varnish," the closely

[1] The report on reproducibility tests is to be published in the *Bulletin of the Bureau of Standards*. The preliminary work was reported on in the *Bureau of Standards Bulletin* 4, 511, 1908; the relation between line intensity and current in same journal, 7, 65, 1911.

[2] Bureau of Standards, Technologic paper, 4.

[3] *Bull. Bur. Standards*, 7, 365 (1911); *J. Ind. Eng. Chem.*, 3, 233 (1911).

adherent, brown coating formed on the walls above the level of the oil. There was found to be no proportionality between the percentages of evaporation, "varnish" and insoluble.

The averages obtained from a large number of determinations are given in the table. The following explanations seem called for. No. 2 was saturated with soap by heating the mineral oil on the steam-bath with a considerable excess of dried and powdered "Ivory" soap; after cooling over night the oil was filtered. No. 3 was saturated with rosin in a similar manner. Nos. 4, 5, 6, 7, 11, and 12 contained each 10 per cent. of the oils stated in the table. To each 10 grams of oil (No. 9) there was added 0.25 gram of Syrian asphalt dissolved in xylene. The sulphur mixture (No. 10) was made by adding 0.01 gram of sulphur, dissolved in xylene, to 10 grams of oil. Each 10 grams of the ferric oxide mixture (No. 15) contained 0.086 gram of "Kahlbaum" ferric oxide. The oxidized oil (Nos. 14 and 16) was exposed to sunlight and air for a month.[1] Owing to the arrangement of the apparatus, No. 16 was more highly oxidized than No. 14.

TABLE SHOWING AVERAGE RESULTS.

(All figures indicate percentages.)

Sample	Contains	"Varnish"	Insoluble	Total Residue
1	Mineral oil, No. 1	0.33	2.26	2.59
2	Soap	0.11	2.06	2.17
3	Rosin	0.27	2.25	2.52
4	Rosin oil	0.21	1.90	2.11
5	Rapeseed oil	1.37	0.01	1.38
6	Lard oil	0.09	0.40	0.49
7	Tallow	0.11	1.37	1.48
8	Mineral oil, No. 2	0.35	2.51	2.86
9	Asphalt	0.29	4.66	4.95
10	Sulphur	0.37	2.52	2.89
11	Paraffin	0.30	2.70	3.00
12	Linseed oil	6.30	0.02	6.32
14	Oxidized mineral oil	0.28	6.00	6.28
15	Ferric oxide	1.02	6.50	7.52
16	Oxidized mineral oil	0.31	7.02	7.33

The apparently high results for "varnish" and correspondingly low results for insoluble in the case of Nos. 5 and 12 are

[1] *Bull. Bur. Standards*, 7, 227 (1911); *J. Ind. Eng. Chem.*, 2, 451 (1910).

due to the greater portion of the insoluble product adhering to the flask, instead of being in the form of a flocculent precipitate, as with the other oils.

Lubricants, for gas engine cylinders, which contain asphalt or which have been exposed to the action of sunlight and air, are to be avoided. It must not be concluded, from the low results obtained with mixtures containing tallow, lard oil, etc., that the addition of these is to be recommended. The presence of the fatty acids resulting from the decomposition of these fatty oils may greatly increase the corrosion of the cylinder and, in actual practice, also cause as much carbonization as the addition of ferric oxide.

Francis Turbine. R. CAMERER. (*Zeits. Vereins Deutsch Ing.*, lv, 2007.)—After a description of the research apparatus, diagrams are given showing how the turning moment, as well as the magnitude and direction, of the blade pressures can be found. Then the description of pressure and velocity in the streaming water is described. The paper is chiefly interesting on account of the numerous diagrams illustrative of the subject.

Glass for X-Ray Tubes. (*Times, Eng. Suppl.*, Dec. 27, 1911.)—It has been ascertained that glass made with lithium is about twice as transparent as soda glass to the photographically active X-rays. Tubes have been produced with a lithium glass "window," through which the rays are discharged from the anti-cathode. This window is about two inches in diameter, and is fused into the bulb immediately opposite the anti-cathode. By using these tubes the exposures necessary for radiographic work are reduced by about 50 per cent.

Melting-point of Seger Cones. R. RIEKE. (*Sprechsaal*, xliv, 726.)—Numerous tests were made on the melting-points of Seger cones, chiefly with regard to the duration of firing and the variety of kilns. These cones have no definite melting-points like metals and most chemical compounds. The chief factor is the duration of firing, which may affect the apparent melting-point by 60° to 100° C. Other conditions being the same, a cone will melt at a lower temperature the more prolonged the firing. According to the author, cones 012a to 1 are an exception; they melt with more difficulty in a slow fire. Cones cannot be regarded as pyrometers for the accurate measurement of temperature, but they have the advantage over optical and thermo-electric pyrometers in the burning of pottery that they are affected by the time factor as well as by the actual temperature attained. A cone that has remained unmelted in one fire cannot be reliably used in a subsequent fire.

Ammonia Production in Great Britain. (BRADBURY AND HIRSCH, Liverpool, Eng.)—The total production of ammonia from all sources, calculated as sulphate, in the United Kingdom (including that used in the manufacture of ammonium soda and other chemical processes) in 1910 and 1911 was

	Tons 1910.	Tons 1911.
Gas works	168,000	169,500
Iron works	20,000	20,000
Shale works	59,000	60,000
Coke and carbonizing works and producer gas plant	120,500	129,000
Total	367,500	378,500

Considering last year's production, it is estimated that England contributed 256,000 tons, Scotland 119,500 tons, and Ireland 3,000 tons. The exports during 1911 reached 292,000 tons and the home consumption 85,500 tons, and 13,000 tons remained as stock carried forward to 1912.

Secondary X-Rays. ANON. (*Revue Sci.*, xxvii, 812.)—Every body struck by light rays becomes luminous in two ways. By diffusion it emits rays of the same wave-length as the incident rays; and if it is fluorescent it can also emit rays of a different wave-length. Similarly, every substance submitted to the action of X-rays becomes in turn a source of X-rays. The emitted, or *secondary rays*, belong to two distinct types: some have the same penetrating power and, in a general way, the same properties as the incident rays; these are the *diffused rays;* the others, totally different to the incident rays, are called *fluorescent X-rays.* Elements with an atomic weight lower than that of sulphur emit almost solely diffused rays. The other elements can give fluorescent rays; these rays are perfectly homogeneous and are characterized by their penetrating power.

Formation of Positive Ions in Heated Metals. Z. KIEMENSIEWICZ. (*Acad. Sci. Cracovie. Bull.*, vi, *a*, 417.)—These experiments were made to ascertain the origin of positive ions from heated metals. Three hypotheses have been advanced: The first accounts for the ions by the presence of absorbed gases; the second, by traces of impurities, and the third considers them to be the result of chemical reaction. The apparatus employed is on the same principle as that used by J. J. Thomson, and the metals investigated include platinum, palladium, gold, iridium, copper, iron, and tungsten. The temperature of observation is 800° C. The results are tabulated, and the conclusion reached is that the absorbed gases are responsible for the production of the positive ions.

FRANKLIN INSTITUTE

(*Proceedings of the Stated Meeting held Wednesday, March 20, 1912.*)

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, March 20, 1912.

MR. WILLIAM C. L. EGLIN *in the Chair.*

Additions to membership since last report, 11.

The communication of the evening was presented by Dr. Edgar F. Smith, Provost of the University of Pennsylvania, on "How the Chemist Uses Electricity."

After an historical review of the early applications of electricity in the chemical laboratory, the rapid precipitation of metals by the use of the electric current was described and illustrated by numerous laboratory experiments.

Specimens of calcium which had been reduced from the chloride by electrolysis were shown. During the course of the demonstrations a number of novel forms of apparatus, including the rotary anode and the mercury cup, were exhibited.

After an inspection of the various specimens the meeting adjourned.

R. B. OWENS,
Secretary.

COMMITTEE ON SCIENCE AND THE ARTS.

(*Abstract of Proceedings of the Stated Meeting held Wednesday, March 6, 1912.*)

HALL OF THE INSTITUTE,
PHILADELPHIA, March 6, 1912.

MR. WILFRED LEWIS *in the Chair.*

The following reports were presented for final action:

No. 2370.—Gray National Telautograph. Elliott Cresson Medal. Adopted.

No. 2466.—Tantalum Wave-Detector. Advisory. Adopted.

R. B. OWENS,
Secretary.

SECTIONS

Mechanical and Engineering Section.—A meeting of the Section was, on invitation, held in the office of the Mayor, City Hall, on Thursday evening, February 29, 1912.

Vice-President Coleman Sellers, Jr., called the meeting to order and first introduced Dr. Allerton S. Cushman, Director of the Institute of Industrial Research, Washington, D. C., who reviewed the progress of road building during the past several years and referred to the changes which were found necessary in this branch of engineering to meet the conditions due to the more extended use of automobiles.

He then introduced Mr. Prévost Hubbard, of Washington, D. C., who presented the communication of the evening on "Bituminous Roads and Pavements, and Their Materials of Construction."

After brief remarks on roads and pavements in general, bituminous roads and pavements were particularly considered. Then followed a description of the various bituminous materials used in road building and the preparation of such materials for road surfaces. Lantern slides of roads, road materials, and apparatus for construction were shown, as well as numerous views of streets and roads.

Adjourned.

R. B. OWENS,
Secretary.

Electrical Section.—A joint meeting of the Section, the Philadelphia Section, American Institute of Electrical Engineers, and the American Society of Mechanical Engineers was held in the Hall of the Institute on Thursday evening, March 7, 1912.

Mr. Thomas Spencer in the Chair.

The paper of the evening, entitled "The Electrification of Main Line Railways," was presented by Mr. W. J. Clark, of New York.

A brief summary of the work of electrification thus far accomplished was followed by the consideration of the various phases of the problem, including cost, operation, equipment, etc. A list of the most important electrifications was given, with statistics as to number of cars, locomotives, and total miles of track.

In the discussion which followed, Messrs. Woods, Darlington, Henderson, and others took part.

The thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

Section of Photography and Microscopy.—A special meeting was held on Friday, March 8, at 8 o'clock P.M., Dr. Henry Leffmann presiding.

Mr. H. Clyde Snook introduced Dr. P. H. Eijkman, of Scheveningen, Holland, the speaker of the evening, and gave a brief outline of some of his work. Dr. Eijkman then presented his paper on "Symphany in Stereoscopic Radiography," in which he described his methods for producing stereoscopic radiographs.

The subject was illustrated by special apparatus and numerous negatives taken by the Roentgen rays.

A recess was taken in order that those present might have the opportunity of examining more closely the various pieces of apparatus and the results obtained by their use.

A brief discussion followed, and the thanks of the meeting were extended to the speaker.

Adjourned.

R. B. OWENS,
Secretary.

MEMBERSHIP NOTES.

Elections to Membership.

RESIDENT.

MR. MORRIS L. COOKE, 216 City Hall, Philadelphia.
MR. W. S. ELLIS, Harrison Building, Philadelphia.
MR. WM. PENN EVANS, care of Baldwin Locomotive Works, Philadelphia.
MR. ARTHUR C. JACKSON, Orthodox Street and Asylum Road, Frankford, Philadelphia.
MR. W. D. KERLIN, Camden Forge Company, Camden, N. J.
MR. E. T. STOTESBURY, Fifth and Chestnut Streets, Philadelphia.

NON-RESIDENT.

MR. THOMAS L. BURTON, 415 North Broad Street, Elizabeth, N. J.
MR. JAMES W. COTTRELL, Hammonton, N. J., P. O. Box 302.
DR. ALLERTON S. CUSHMAN, Institute of Industrial Research, Nineteenth and B Streets, N. W., Washington, D. C.
MR. L. A. OSBORNE, P. O. Box 911, Pittsburgh, Pa.
NAVAL CONSTRUCTOR ELLIOTT SNOW, U. S. N., care Wm. Cramp & Sons, Philadelphia.

Changes of Address.

MR. NORMAN MACBETH, 166 West Seventy-second Street, New York, N. Y.
MR. GEORGE C. REESE, 112 North Nineteenth Street, Flatbush, Brooklyn, N. Y.
MR. GEORGE MACLEAN, Room 100, Van Dyck Studio, 18 West Thirty-fourth Street, New York, N. Y.
MR. CHARLES H. DAVIS, 18 Old Slip, New York City, N. Y.
MR. WM. A. NETTLETON, Ballston Lake, New York, N. Y.
MR. R. HERBERT CROWELL, 237 East Main Street, Moorestown, N. J.
DR. T. C. MENDENHALL, Ravenna, Ohio.
MR. F. S. ALLEN, 56 Prospect Street, Hartford, Conn.
MR. EDWIN S. BALCH, 311 South Fifteenth Street, Philadelphia.

NECROLOGY.

Charles Edward Ronaldson was born in Pottsville, Pa., October 3, 1846, and died February 20, 1912, at his home, 4017 Locust Street, Philadelphia.

Mr. Ronaldson was a student in the University of Pennsylvania, from which he received the degree of Bachelor of Arts, and in 1869 he received the degree of Mechanical Engineer from Lehigh University.

During his professional career he served the Lehigh Valley Railroad at

Delano, Pa., in 1874; became agent in the United States for the Siemens patent metallurgical gas furnaces, continuing in this capacity until 1889. For several years he was assistant to Major Hibbard in the construction of the immigration depot at Ellis Island, New York, and later served as New York representative of the George V. Cresson Company, of Philadelphia.

Mr. Ronaldson was a trustee of Lehigh University from 1877 to 1879, and an honorary member of the Lehigh Alumni Association; he became a member of the St. Andrew's Society in 1869, and was its secretary at the time of his death. He was much interested in the work of the Bartram Association of Philadelphia, and for nearly forty years was connected with the Masonic fraternity.

He became a member of the Franklin Institute in 1874; was elected to its Board of Managers in 1885, serving until 1893. He was re-elected in 1908 and served to the time of his death.

He was a member of the Committee on Science and the Arts for many years, and served on the Committee on Library since 1903, being its chairman during the years 1907 and 1908.

Prof. Henry Wilson Spangler was born at Carlisle, Pa., January 18, 1858, and died in Philadelphia on March 17, 1912. He was graduated from the United States Naval Academy in 1878, and was an engineer in the United States Navy from that time until 1889.

In 1898, during the Spanish-American War, he again served in the navy for a short time.

He was called to the University of Pennsylvania in 1881 to the assistant professorship of Mechanical Engineering, and in 1889 was made head of the Mechanical Engineering Department, holding the Whitney Professorship of Dynamical Engineering.

In 1896 the University conferred upon him the degree of Master of Science, and in 1906 the degree of Doctor of Science.

Professor Spangler was a member of the advisory council of the Engineering Congress, held at Chicago in 1893; a member of the Jury of Awards of the Buffalo Exposition in 1901, member and past president of the Engineers' Club of Philadelphia, and a member of many scientific and technical organizations.

He was the author of numerous books and pamphlets dealing with scientific and technical subjects, among the many important of which are his well-known "Valve Gears" and "Notes on Thermodynamics."

Professor Spangler's connection with the Franklin Institute dates back to 1883. He served the Institute on numerous committees, notably as a member of the Committee on Science and the Arts.

George Wallace Melville, Rear Admiral U. S. N., died March 17, 1912. Admiral Melville was born in New York on January 10, 1841. His technical education was begun at the Polytechnic School of Brooklyn and under private tutors.

At twenty years of age he was an officer of the Engineer Corps of the United States Navy, and during his forty years of service he became

CHARLES E. RONALDSON
1846-1912

OBERLIN
COLLEGE
LIBRARY.

engineer, chief engineer, commander, engineer-in-chief U. S. N., and finally rear admiral, being placed on the retired list January 7, 1903.

As chief of the Bureau of Steam Engineering he made numerous changes in the design of propulsive equipment of warships, and during the Spanish-American War fitted out the repair ship *Vulcan*—a complete floating machine shop, which performed excellent service.

In the earlier years of his connection with the navy Admiral Melville devoted much time to Arctic exploration. In 1873 he volunteered his services and became a member of the expedition sent to rescue the crew of the *Polaris*, which had gone in search of the North Pole under Captain Charles F. Hall.

Six years later the *Jeannette* expedition was proposed, and Admiral Melville again volunteered.

For a third time, in 1884, he visited the polar region with Winfield S. Schley on an expedition organized for the relief of Lieut. A. W. Greely. The narratives of these expeditions may be found in the various official documents published by the United States Government and others, and need not be detailed here.

For his services in this connection he was awarded a gold medal by Congress.

He won many honors through his attainments. The Order of St. Stanislaus was conferred upon him by the Czar of Russia, and he received honorary degrees from the Stevens Institute of Technology, University of Pennsylvania, Harvard, Columbia, and Georgetown universities. He was an honorary member of the leading scientific and engineering societies of the world.

In recognition of his achievements as an engineer he was elected an honorary member of the Franklin Institute in 1899.

Mr. Addison B. Burk was born in Philadelphia in 1847 and died on February 27, 1912. He was educated in the Philadelphia public schools. While still a youth he became a photographer, but later connected himself with the *Germantown Chronicle* as reporter and editor. For thirty years he was connected as reporter, associate editor, editorial writer, and managing editor of the *Philadelphia Public Ledger*.

He organized the first manual training school in Philadelphia.

Mr. Burk took a deep interest in the work of the Spring Garden Institute, of which he was president during the last twenty years.

He was also a member of the Board of Trustees of Drexel Institute and a director of the Hayes Mechanics' Home.

He was greatly interested in building societies, and was an officer of the Building Association League of Pennsylvania and the National League of Building Associations.

Mr. Burk's membership in the Franklin Institute dated from 1891.

Mr. William B. Hollis, Philadelphia.
Mr. Charles Hunter, Philadelphia.
Mr. William Mitchell McAllister, Philadelphia.

LIBRARY NOTES.

Purchases.

MILLER, BERRY & RILEY.—Problems in Thermodynamics and Heat Engineering. First edition.

Journal of the Society of Chemical Industry.—Index, 1896–1905.

Whitaker's Almanack for 1912.

International Catalogue of Scientific Literature.—F. Meteorology. Ninth issue. G. Mineralogy. Ninth issue.

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Tasmania, Secretary for Mines, Annual Report, 1909 and 1910. Hobart, 1910–11. (From the Secretary.)

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General Society of Mechanics and Tradesmen of the City of New York, Annual Report for 1911. New York, 1912. (From the Society.)

Shanghai Society of Engineers and Architects, Proceedings, vols. 9 and 10, 1909–1910. Shanghai, 1911. (From the Society.)

BOOK NOTICES.

ELECTRO-ANALYSIS. By Edgar F. Smith, Blanchard Professor of Chemistry, University of Pennsylvania. Fifth edition, revised and enlarged, with forty-six illustrations. Philadelphia, P. Blakiston's Son & Co., 1911. $2.50 net.

The introduction is followed by a description of the several sources from which electric current is usually obtained for electrochemical work. Methods of current control and variations and methods of current voltage measurements are next discussed; then an excellent description of the chemical laboratory of the University of Pennsylvania, an historical sketch of analytical methods involving the use of the electric current, theoretical considerations involved in electro-analysis, rapid precipitation of metals electrolytically, and the use of the mercury cathode.

In the second or special part of the work the various methods for the electrolytic determination of the metals, by means of stationary and rotating anodes, and of the mercury cathode, are given in detail. Directions for the determination of lead and manganese by the electro-deposition of their diox-

ides at the anode, and of uranium and molybdenum by the electro-deposition of their hydrated oxides at the cathode, are also given.

Various modes for the separation of metals are then discussed at length.

The applications of the current to the quantitative determination of non-metals occupy the greater portion of the concluding chapters. Thus the determination of the halogens and of nitric acid electrolytically, the oxidation by means of the current of the sulphur and arsenic natural sulphides and arsensides and of the chromium of chromite, and the combustion of organic compounds electrolytically are discussed, while a description is given of the double cup and its application in the determination simultaneously of anions and cations and in the separation and determination of the metals of the alkalies and of the alkaline earths.

Copious references to the original literature are given. The illustrations and presswork are excellent.

The present edition of this authoritative work on electro-analysis will undoubtedly be welcomed by the increasingly large number of workers in this field.

COCHRANE HEATERS: THEIR USE IN STEAM POWER PLANTS. Harrison Safety Boiler Works, Philadelphia, 1911. Catalogue No. 500. 144 pages, illustrations, 8vo. Free on application to publishers.

The range of topics included in this catalogue embraces: the choice of a system for heating boiler feed-water; means for utilizing exhaust steam; boiler scale, temperature strains, and corrosion; removal of oil from exhaust steam; pumping hot water; water softening, and the metering of feed-water, etc., the whole forming a very complete account of what might be termed "exhaust steam engineering."

The catalogue describes, in connection with the above-mentioned branches of engineering, the Cochrane open feed-water heaters; steam stack and cut-out valve heaters and receivers; multiple unit heater arrangements; the Sorge-Cochrane hot-process softening systems; the Cochrane combined heaters and meters, steam and oil separators. The work is supplied with numerous half-tone cuts illustrating the application of these devices to steam plants of various kinds, and should prove of considerable value to owners, engineers, and operators of steam plants and of interest to others.

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Les Peintures par François Margival. Encyclopedie Scientifique des Aide-Memoire. 164 pages, 12mo. Paris, Gauthier-Villars, no date. Price, in paper, 3 francs.

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tions, plates, maps, 8vo. Economic Paper No. 23. The Mining Industry in North Carolina During 1908, 1909, and 1910. By Joseph Hyde Pratt, Ph.D., and Miss H. M. Berry. 134 pages, illustrations, 8vo. Raleigh, State Printers, 1911.

American Telephone and Telegraph Company. Annual report of the directors to the stockholders for the year ending December 31, 1911. 51 pages, illustrations, plate, 8vo. New York, 1912.

Canada Department of Mines, Mines Branch. Preliminary report on the mineral production of Canada during the calendar year 1911. Prepared by John McLish, B.A., Chief of the Division of Mineral Resources and Statistics. 24 pages, 8vo. Ottawa, Government Printing Bureau, 1912.

Cyaniding made easy and continuous by adopting the mechano-chemico lixiviator for the rapid and effective dissolving of gold, silver, and copper. 19 pages, plates, 16mo. Philadelphia, W. L. Imlay, no date.

Questioned Ink Marks. Two papers, containing new and important information concerning the determination of the age and identity of ink marks. By Webster A. Melcher, LL.B. 19 pages, 8vo. Philadelphia, 1912.

Michigan State Board of Health. Thirty-eighth annual report of the Secretary for the fiscal year ending June 30, 1910. 171 pages, illustrations, 8vo. Lansing, State Printers, 1911.

U. S. Mines Bureau. Technical Paper 8. Methods of Analyzing Coal and Coke. By Frederic M. Stanton and Arno C. Fieldner. 21 pages, illustrations, 8vo. Washington, Government Printing Office, 1912.

Iowa State College Engineering Experiment Station. Sewage Disposal Plants for Private Houses. 44 pages, plates, 8vo. Ames, Iowa, College, 1909.

Annuaire pour l'an 1912, publié par le Bureau des Longitudes. Avec notices scientifiques. 750 pages, illustrations, 16mo. Paris, Gauthier-Villars, no date. Price, in paper, 1 franc, 50c.

Annuaire-statistique International des installations d'epuration d'eaux d'egouts au 1er Juillet, 1911, par B. Berzault. 175 pages, illustrations, plates, maps, 8vo. Paris, Masson et Cie., 1911.

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Carnegie Institution of Washington. Annual report of the Director of the Department of Terrestrial Magnetism, 1911. 12 pages, map, 8vo. Reprinted from Year Book No. 10, pages 198-207, plate 9.

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U. S. Geological Survey. Mineral Resources of the United States. Calendar Year 1910. Part 1, Metals; part 2, Non-metals. 2 volumes, illustrations, maps, 8vo. Washington, Government Printing Office, 1911.

CURRENT TOPICS

Improvements in Pyrometers. R. S. WHIPPLE. (*Electrician*, lxviii, 132.)—This article describes some improvements which will increase the value of pyrometers in industrial work. W. S. Peake's compensating leads are described, in which an alloy of copper, with a very small proportion of nickel, is used, which gives the same electromotive force against copper as the platinum couple, and yet has a resistance only very little greater than that of pure copper. Cold junction control is discussed and the toluol regulator or cold junction thermostat as designed by H. Darwin is described. Then Peake's scale control box for use with thermo-electric pyrometers is referred to, and the Brearly recalescence curve tracer and a thermo-couple potentiometer, designed to measure accurately small potential differences not exceeding 30 millivolts. Accounts are given of the Joly meldometer, the Féry spiral pyrometer, and, finally, of the Whipple-Féry pyrometer, which is designed to determine the temperature of molten iron and steel. This is a modification of the Féry radiation pyrometer, in which the concave mirror is permanently fixed in position at the open end of a long tube which is closed at the other end. The mirror is permanently focused on the inside of this closed end, and it projects a heat image of the closed end on to a small thermo-couple as in the standard Féry pyrometer. No focusing or other adjustments are required, and it is found that in practice a temperature can be determined in about one minute.

Influence of Acid in Dyeing with Chrome Dyestuffs. E. RISTENPART. (*Färber-Zeit.*, xxii, 477.)—The nature and the quantity of the acid used in dyeing wool with dyestuffs which require to be afterchromed are of importance, for an excess of acid, especially of mineral acid, frequently weakens or dulls, or even entirely changes, the shade obtained.

Soot Fall in London. (*The Times*, Jan. 8, 1912.)—As a result of a series of investigations extending over twelve months, the *Lancet* calculates that the annual deposit of soot on the administrative county of London, including the city (117 square miles), amounts to 76,050 tons, containing over 6,000 tons of ammonia, 8,000 tons of sulphates, and 3,000 tons of chlorine as chlorides. These figures are deduced from the amount of soot collected at the city station; taking the Southwestern metropolitan station as a basis, the annual deposit would average 53,820 tons.

"Elektra" Dry Fire Extinguisher for Electric Installations. R. NAGEL. (*Elektrotechnik und Maschinenbau,* xxix, 581.)—This is the Elektra Trockenfeuerlöscher made by H. Künzel, of Köln-Lindenthal. The tests were made in the Cologne municipal electricity works. The apparatus is a slightly conical tube, 750 mm. long, charged with a white powder which liberates carbon dioxide when heated; the tube consists of an insulating material, 2 mm. thick. The powder stood 50,000 volts alternating for five minutes when forming a bridge between terminals of the horn type. Arcs were extinguished by throwing the powder on them, and a fire built of wood soaked in petroleum, sending up flames close to two vertical bus-bars under 12,000 volts alternating, was extinguished without danger to the operators and without causing strong current fluctuations.

Battery Truck-cranes for Handling Freight. ANON. (*Eng. Record,* lxiv, 60.)—Each truck is an electric vehicle with a swinging crane mounted on the front end. The hook of the crane is raised and lowered by a 1-ton hoist mounted at the back of the crane; the motors driving the hoist and the vehicle are operated from a battery at the rear end of the vehicles. If the parcel is not to be moved over 10 feet vertically it can be deposited within a 6 foot to 8 foot radius, the vehicle remaining stationary; or the parcel may be lifted and the vehicle moved to the point of deposit. The vehicle has a short wheel-base and can exert a draw-bar pull of 2,000 pounds.

A Silica Standard of Length. G. W. C. KAYE. (*Roy. Soc. Proc., Ser. A,* lxxxv, p. 430.)—In making primary standards of length objections are made to (1) copper alloys, (2) platinum, (3) iridio-platinum, (4) nickel, and (5) invar for various reasons. Fused silica has a remarkable combination of good qualities: (*a*) very small thermal expansion, (*b*) very small thermal hysteresis, (*c*) cheapness, (*d*) low density; while its weak points, *viz.*, (*a*) frangibility, (*b*) comparatively low elasticity, and (*c*) slight solubility in water, can be treated as negligible when used only by skilled operators, as is the case with primary standards. The present metre standard, the first of its kind, consists of a tube of silica with horizontal slabs of the same material fused into its ends. These slabs are optically worked, plane and parallel. The under sides are platinized, and the defining lines of the standard are made by ruling through the platinum film with a diamond. The standard is supported at the Airy points. Care is taken to allow for viewing the defining lines through the slabs, also for viewing through water or other liquids. The standard was annealed by slowly raising it to 450° C., maintaining it at that temperature for eight days, and slowly cooling it during fourteen days. Annealing caused a shrinkage of about one-half a micron.

The Constitution and Formation of Portland Cement. E. LEDUC. (*Bull. Soc. d'Encourag.*, cxvi, 280.)—The properties of the silicates, aluminates, and ferrites of calcium were investigated, and by preparing cements of varying composition light has been thrown upon the effects of the several ingredients on the properties of Portland cement. Great care was taken throughout to ensure thorough mixing of the ingredients by repeated grindings and siftings, and to obtain each ingredient free from interfering impurities. *Monocalcium silicate* (SiO_2,CaO) has no hydraulic properties. *Dicalcium silicate* (SiO_2,2CaO) has no hydraulic properties and spontaneously falls to powder on cooling. It is decomposed by water to mono-calcium silicate and calcium hydroxide. It cannot, therefore, be prepared in the wet way. Attempts to prepare *tri-calcium silicate* (SiO_2, 3CaO) were unsuccessful. *Mono-* and *di-calcium aluminates* (Al_2O_3, CaO and Al_2O_3, 2CaO) both possess hydraulic properties and are stable in hot water. *Tri-calcium aluminate* (Al_2O_3, 3CaO), as prepared, hardened quickly, but swelled out in boiling water. *Ferrites* do not possess hydraulic properties. *Silico-aluminates and silico-ferrites.*—The most basic of these compounds prepared had the composition: SiO_2, 2.6CaO plus 4 per cent. of alumina or ferric oxide in the form of Al_2O_3, 2CaO, or Fe_2O_3, 2CaO. *Cement.*—The temperature of burning of normal products and those containing 24 per cent. of clay is 1400°–1500° C. As the proportion of clay diminishes the temperature required is higher. The replacement of alumina by ferric oxide weakens the cement. A high content of magnesia causes the cement to swell. The author noted that certain Seger cones appeared to melt at temperatures somewhat distant from those indicated, and made tests of the cones in comparison with a Le Châtelier pyrometer, and gives tables of results.

Change in Length of Hardened Steel. A. LEMAN AND A. WERNER. (*Zeitschr. Instrumentenkunde Beib.*, xvi, 167.)—Experiments made on end-standard of length show that changes occur after hardening if the standards are maintained at a temperature of 150° C. for several hours. After a given time, six hours in some cases, no further change occurs. The lengths are measured every hour during the process.

Volt-hour Meters for Tramway Systems. R. G. AND J. G. CUNLIFFE. (*Electrician*, lxvii, 971.)—In its simplest form it consists of a direct current motor having a moving armature specially designed so that its speed is proportional to the voltage. The meter is arranged to read in volt-hours on a dial with great accuracy. It can be had used either in a stationary position or on a car, and is not subject to the errors that trouble instruments which record by a pen. Owing to its simple construction it can be purchased at a comparatively low cost.

Treatment of Refractory Elements for Incandescent Lamp Purposes. R. E. MYERS. (*Trans. Amer. Inst. Chem. Eng.*, iii, 172.)—After discussing the properties necessary in an element for the manufacture of electric incandescence lamp filaments, the author briefly describes the manufacture of tungsten filaments. The raw material is crude tungstic acid, which has to be purified very carefully. The most deleterious impurities probably present are molybdenum, arsenic, and phosphorus. For this Smith and Exner's process (*Proc. Amer. Phil. Socy.*, xliii, 123) is used. Ammonium paratungstate crystals are added to boiling nitric acid (1:1 by vol.), and hydrochloric acid is added from time to time, and the heating is continued until only traces of chlorine remain. The tungsten oxide is then washed, again converted into paratungstate, and the treatment repeated until the tungsten oxide will dissolve completely when digested with a dilute solution of sodium carbonate. To prepare the plastic mass from which the filaments are squirted, three methods may be used: (1) the tungsten compound, preferably the brown oxide (WO_2) or the violet oxide (W_2O_5), is mixed with an organic binder (nitrocellulose dissolved in amyl acetate, gelatin, starch, gum tragacanth, etc.); (2) tungstic acid is reduced to finely-divided metallic tungsten, and the latter is mixed with an organic binder, or dissolved in an amalgam of cadmium or bismuth; (3) ammonium tungstate or tungstic acid, without the addition of a binder, is worked into a pasty mass, which will flow under pressure. The diamond dies used in squirting the filaments have apertures from 0.001 to 1.015 inch diameter. At this stage the filaments are usually practically non-conducting and are subjected to a heat treatment to reduce their electrical resistance. Those consisting of tungsten oxide and an organic binder are heated to 400° C. in an atmosphere of hydrogen; those consisting of metallic tungsten and an organic binder are heated to 600° C. in a non-oxidizing atmosphere produced by the decomposition of the binder, but if an amyl acetate solution of nitrocellulose has been used as a binder, they are heated slowly to 1200° C. *in vacuo*. Filaments obtained by the amalgam process are heated, preferably in a vacuum, at comparatively low temperatures. All the filaments are then subjected to a final heating by means of an electric current in a non-oxidizing atmosphere to remove the last traces of the binder. Reference is made to the recent production of ductile tungsten and molybdenum and to the advantages of the "wire-type" tungsten lamp, both in respect to mechanical strength and electrical properties. It is intended to manufacture lamps of this type of 400 to 500 candle-power to compete with arc lamps. It is claimed that the 400-candle-power lamp gives more light than the ordinary enclosed arc lamp and has a slightly higher efficiency. Lower power "wire-type" lamps are especially suitable for car lighting. Molybdenum is of no use for lamp filaments, but is quite suitable for the manufacture of supports for the filaments.

Electrolytic Bullion Refining in United States. E. B. DURHAM. (*Amer. Inst. Mining Engin.*, lviii, 811.)—The electrolytic process was installed in the Philadelphia Mint in 1902, in the Denver Mint in 1906, and in the San Francisco Mint in 1908. It will also be used in the New York Assay Office on the completion of the new building. The mints and assay offices accept bullion carrying more than 200 thousandths of precious metals. The costs of refining run from 1 cent per ounce on good silver bullion to 8 cents per ounce on bullion carrying 800 thousandths base. The costs on ordinary gold bullion average 4 cents per ounce. On account of these high costs on very base bullion, most of it is sent to private refineries where the facilities for handling this grade of material are better and the refining charges, therefore, less than at the mints. At the San Francisco Mint bullion containing silver is treated in cells charged with a nitric acid electrolyte. These cells produce fine silver and leave a residue rich in gold. This residue, together with the crude gold bullion, is treated in cells having a chloride electrolyte. These produce fine gold and leave a residue containing silver chloride. This is reduced to the metallic state with zinc, and is then treated in the silver cells. The different waste solutions and the wash waters, after being freed from the bulk of their precious metals, still contain copper and other metals. These are removed by scrap iron, and are then treated in the copper cells having a sulphate electrolyte. These cells produce pure copper and collect a residue containing lead, some gold and silver, and all the metals of the platinum group originally in the bullion. This residue is relatively small, and is melted into bars and stored until sufficient accumulates for treatment. The initial treatment of the bullion is in vertical cells, a modification of the Moebius cell, devised at the Philadelphia Mint. The scraps from the vertical cells are re-treated in the horizontal cells, a modification of the Thom cells. Each type of cell has its advantages and disadvantages. The Wohlwill gold process is used at all the mints; this was the outcome of experiments to separate platinum from gold.

Black Waterproof Dressing. ANON. (*Amer. Mach.*, xxxv, 18, 850.)—A black waterproof dressing for railway and wagon coverings, tarpaulins, etc., can be made by mixing together 7 pounds best black paint, ½ pound powdered litharge, 1 pint oak varnish, ½ pint boiled linseed oil, and ½ pint thick boiled oil. Apply as an ordinary paint.

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